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ICE-RETREAT IN GLACIAL LAKE NEPONSET AND IN SOUTHEASTERN MASSACHUSETTS.

INTRODUCTION.

LAKE NEPONSET is the name applied to the body of water which, during the final retreat of the Wisconsin ice-sheet, occupied the upper portions of the valley of the present Neponset River a few miles south of Boston. The existence of this lake was first pointed out by Professor W. O. Crosby, who regarded it as one of a series of more or less open lakes, the waters of which had gathered between the general ice-margin and the higher lands bordering the northward-sloping valleys in the region to the southwest, south and southeast of Boston during the period of retreat. The more important of the water bodies beginning at the west are designated by Professor Crosby as Lakes Sudbury, Charles, Neponset, and Bouvé. The deposits and history of Lake Bouvé have been discussed in detail by Dr. A. W. Grabau, while the Sudbury, Charles, and Neponset lakes have been defined and discussed in a more general way by Professor Crosby and Mr. F. G. Clapp.

In the writings of Crosby, Grabau, and Clapp,[1] the view, though not definitely stated, seems to have been tacitly accepted that, although there were doubtless many minor irregularities of the ice-front, the margin as a whole preserved a rather definite and regular terminal

[1] For MR. CLAPP'S present views see paper on "Relations of Gravel Deposits in the Northern Part of Glacial Lake Charles, Massachusetts," pp. 198–215 of the present number of the JOURNAL OF GEOLOGY.

facing, such as characterizes living glaciers. It was apparently conceived by the writers named that, as the face drew back to the north, a line of glacial lakelets came into existence at the heads of the northward-leading valleys. These, as the ice retreated, were considered to have grown in size and to have coalesced until the Sudbury, Charles, and Neponset lakes, and possibly also Lake Bouvé, became united into a single lake many miles in width and length, and of considerable area.

The studies of the present writer in Lake Neponset have led to the conclusion that the ice in that region, instead of retreating with a definite and somewhat regular front, had become absolutely stagnant before the history of the lake began, and that its disappearance was characterized by marked irregularities along lobes, deep re-entrants and detached blocks being the rule rather than the exception. Moreover, the marginal distribution of the deposits makes it seem probable, if not certain, that there was no general body of water such as was postulated for the Sudbury-Charles-Neponset stage, or even for the simple Neponset stage itself, but that the deposits, generally considered as marking the lake level or levels, were laid down in a series of small and more or less independent lakelets existing along the margins of the residual valley lobes or about entirely detached masses of ice.

In urging the improbability of the existence of large lakes with definite levels in this region during the earlier stages, however, the writer does not wish to be considered as denying the existence of considerable bodies of water in the lower portions of the valleys during the closing stages of the lakes when the ice-lobes and blocks had practically disappeared. In the following discussion of Lake Neponset the terms "lake" and "bay" are used to designate those portions of the basin of the Neponset River and its tributaries in which glacial sediments were laid down in standing water irrespective of time, elevation, or of the character of the water bodies in which the deposition took place.

Stoughton Bay is simply a portion of the Neponset basin, lying in the vicinity of the town of the same name. In this bay the conditions which the writer believes to have characterized the ice-retreat in the region under discussion are recorded very definitely in the

distribution and topographic expression of the deposits; and, as the history of the retreat in this locality is believed to be essentially the same as in the other glacial lakes of the region, the bay has, for the purpose of discussion, been selected as a type.

STOUGHTON BAY AREA AND ITS DEPOSITS.

Topography and drainage.—In a broad way it may be said that Stoughton Bay occupied a somewhat oval area surrounded by an interrupted belt of hills which, starting northwest of North Stoughton, extends southward about four miles, and then curves first to the west and then to the northwest, finally terminating in the range of hills southwest of Canton. The breadth of this basin is about four miles, and the length a trifle greater. The crests of the hills constituting the boundary vary from 200 up to 420 feet in altitude, while the intermediate cols vary from 190 to 250 feet in elevation.

Notwithstanding these relatively low gaps in the southern rim of the basin, it seems probable that the preglacial drainage, like that of the present period, was by way of the Neponset River to the north. Both the lower level of the rock-floors of the channels and the greater width of the valleys at the northern end of the area bear out this supposition. The possibility of a deflection of the drainage to the southwest through the valley now occupied by Massapoag Pond, has been considered, but although the valley is relatively broad, the frequent projection of rock "islands" through the outwash drift deposits, with which it is filled, appears to indicate that the rock bottom is much higher than in the present valley at Canton Village. The Canton valley, however, is not a broad one, the rock outcropping at relatively short distances from the stream on both sides, and probably underlying it at no great depth. The high elevation of the bottom of this channel, as compared with the low elevation, which probably characterizes the near-by Neponset valley bottom, would appear to indicate, either that the former is not the main preglacial drainage channel, or that the Neponset valley has been materially deepened by glacial erosion. The latter appears to be the more probable. In fact, the drainage and topography of even the bed-rock areas of this portion of Massachusetts show very few of the characteristics of normally developed drainage systems.

Relatively little is known as to the minor details of the rock topography within the basin, as the floor is deeply covered, except perhaps in the center, with extensive planes of stratified drift, which rises in places to nearly 150 feet above the marshy tracks along the main streams, which in turn are of unknown, though probably not very great, elevation above the rock-floors beneath them. The wells in the region are generally shallow, and in most instances afford little information of value. The details of the plains and of the cols in the rock-rim, many of which served as channels for the overflowing waters, can be considered to the best advantage in the discussion of the various stages in the history of the bed.

STAGES OF DEPOSITION.

The history of the Stoughton Bay area of Lake Neponset may be said to have begun when the first body of water came into existence between the ice and the retaining walls of the basin. Such a lakelet must of necessity have been of small size at the beginning, but soon became enlarged through the melting back of the ice. The outlets may have been over low points in the rock-rim, or along the edges of the ice. As the melting progressed, the expansion of the lakelets continued until the lower outlets of the waters were uncovered.

The different levels of the waters are indicated approximately by the altitude of the stratified deposits, which were laid down during the different stages. In Stoughton Bay these deposits are of two general levels, the higher standing at 250 feet, and the lower at about 190 or 200 feet above the level of the sea. The higher stage is named from the town of Stoughton, the greater part of which is located on the high-level deposits, while the lower stage is named from the village of Springdale, near which the lower planes are strongly developed.

The distribution of the materials show that not all the deposits, even of a single stage, were laid down in the same body of water, but accumulated, on the contrary, in more or less separate lakelets. The principal water bodies of the higher stage were the Rattlesnake Hill, East Sharon, and Stoughton lakelets, while the leading bodies of the lower stage were the Elm and Springdale lakelets.

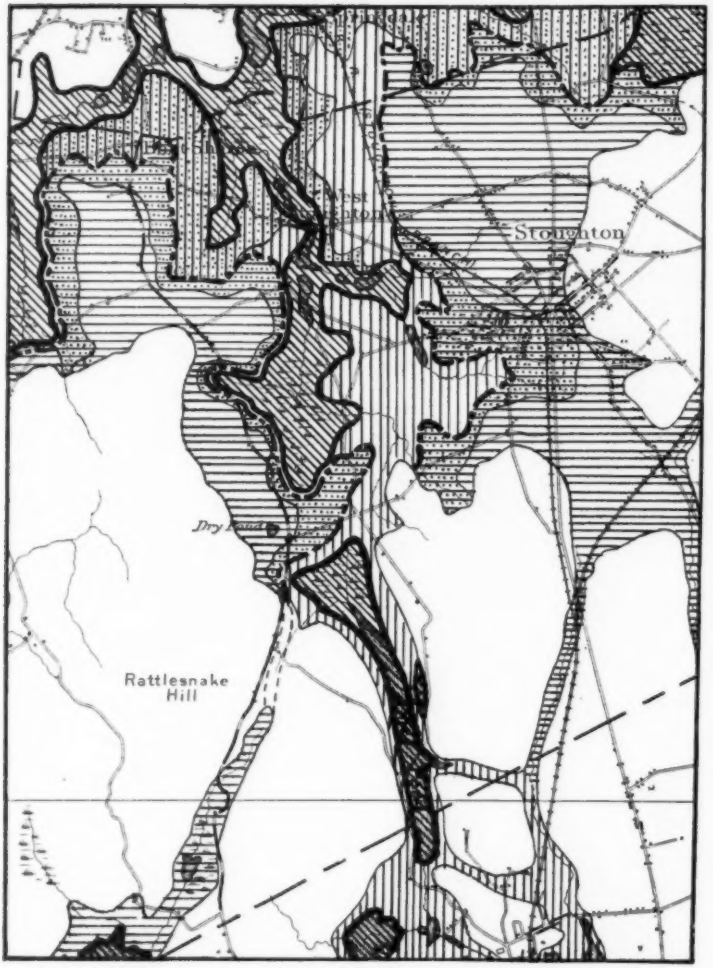

FIG. 1.—Retreatal Stages in Stoughton Bay of Glacial Lake Neponset.

Rock and till, generally higher than "high-level" plains.

High-level plains and outwash of East Sharon and Stoughton lakelets.

Gradation deposits between high- and low-level plains.

Low-level plains and outwash of Elm Street and West Stoughton lakelets

Gradation deposits below low-level plains.

Ice-masses at close of low-level stage of lakelets.

Position of ice-margin at opening of high-level stage.

Position of ice-margin at close of high-level stage.

Position of ice-margin at close of low-level stage.

EARLIER OR STOUGHTON STAGES.

Rattlesnake Hill lakelet.—This is the smallest of the recognized lakelets of the Stoughton Bay area, being less than half a mile in length and only about one-eighth of a mile in width. It was formed in a re-entrant just north of the col between Rattlesnake Hill, rising to 420 feet on the northwest, and another granitic hill, about 360 feet in height, on the southeast. The rock-floor of the col is not now exposed, but as there was free drainage to the south, the deposits though constituting a somewhat broad and flat sheet, are probably of slight thickness at the crest. The surface of these deposits stands at 250 A. T.

The deposits of the locality may be divided into three classes: (1) the outwash deposits in the channel leading southward from the

FIG. 2.—Diagrammatic north-south section through Rattlesnake Hill divide, showing outlet and broken delta deposits. (*A*, *B*, etc., show successive stages of ice-front during its recession.)

col; (2) the flat top deposits at and just north of the crest; and (3) the irregular and broken delta deposits on the north (Fig. 2).

The outwash gravels, which constitute a gentle sloping deposit extending down the valley to the southward, were evidently formed not later than the period when the ice-margin rested at the point represented by *A*, as the unfilled kettles and other depressions between the imperfect deltas to the north indicate that in the later stages little or no material was being carried into the lakelet.

The deposits at and just north of the crest consist of sands and fine gravels, and evidently represent the perfected lake deposits. They present an almost perfectly flat surface, one-eighth of a mile in width, and perhaps twice as long, which is so ill drained that in the wetter seasons the water stands over several acres, though of a depth of only a few inches. It is now the site of a cranberry bog. From this flat the rock hills rise with a sharp line of demarkation abruptly on each side.

At the time the deposits were laid down the ice probably presented a fairly definite face to the lake, the position being not far from the crest of the pass possibly near *A*. Later, however, the margin became broken up into detached blocks at its edge, the location of these blocks being represented by the imperfect planes and kettles lying just north of the crest. Continuing to the north, the deposits of stratified material end rather abruptly, the lower portions of the northward-leading valley, through which the ice drew back, being practically free from them. This would seem to indicate, either that the glacial streams had been diverted at some point farther north, or that they no longer carried any material quantities of sediments. Otherwise the deposits would have continued to accumulate in the lakelet which, in the later stages, must have reached some distance to the north of the deposits previously noted. The waters passing out from the lake to the south, being no longer overloaded with materials carried in suspension, began the work of eroding out the deposits laid down in the earlier stages, with the result that a thickness of ten feet of sand and gravel was removed throughout nearly the entire width of the valley leading south from the pass, the original level being represented only by an occasional terrace remnant standing about ten feet above the present valley floor. Imbedded in the silt, which here constitutes the floor, is a granitic bowlder, nearly fifteen feet in diameter, probably stranded on the rock or till surface underlying the silts during the melting of the ice and surrounded by subsequent deposits of sand.

East Sharon lakelet.—This name is applied to the body of water which lay between the granitic hills, one and one-half miles south of East Sharon, and the ice-front after the latter had shrunk back from the valley sides. The lakelet had a total length of approximately two and one-half miles. The greatest extent of open water was south of East Sharon (southwest of West Stoughton), where the lake measured a mile or more across. A mile southwest of West Stoughton the lake became contracted into what must have been simply a rather broad and sluggish lateral stream,which, however, opened up again to the southward into a marginal body, one-quarter of a mile or more in width, which continued to the north base of Rattlesnake Hill.

In this compound lakelet the deposits of the East Sharon stage

were laid down by the superglacial streams from the surrounding ice. The sand and gravel plains are most perfectly developed along the hillsides, as the lakelet was there shallowest and soonest free from ice. In such situations the plains were frequently built up to a horizontal upper surface, coinciding approximately with the water level, and are generally free from kettles. As the ice receded, lower portions of the hillsides were uncovered, and the water became deeper. The ice, however, melted back most rapidly along the surface of the lakelet, leaving projecting edges beneath the water, which became covered with sands and gravels. On the further melting of the ice and its disappearance from beneath these gravels, the materials were let down into irregular accumulations along the sloping valley sides, constituting the gradational deposits between the upper and lower plains, and between the lower plains and the present valley floor in the Stoughton Bay area. When the ice-wedge was very thin, gentle and fairly regular slopes resulted when the materials were let down, but when thicker, steeper and kettle-pitted slopes resulted. Dry Pond, in the southern part of East Sharon, is an example of such a kettle. This is the explanation of the change from a flat to a gently sloping plain, and finally to the irregular hummocky slopes which characterize the plains at many points in this area. The steeper ice-contact slopes, which are especially well developed in portions of the east side of the East Sharon plain, were formed where the marginal ice-wedge was only slightly developed. That the slopes of the plains cannot be regarded as purely depositional is shown by the fact that the inclination of the surface is opposite that exhibited by delta plains.

FIG. 3.

FIG. 4.

FIGS. 3 AND 4.—Showing mode of formation of gradational deposits: 3, marginal deposits before recession of ice; 4, plain and gradation deposits after recession of ice.

There can be no question that the materials of the plains came from the ice. This is attested by the rounding of the pebbles, the

lack of agreement in composition between the gravels and the adjacent rocks or tills from which they must otherwise have been derived, and the absence of even the most local postglacial deposits of similar character in the region.

The lake-level was regulated by the altitude of its outlet, which was through the notch southeast of Rattlesnake Hill, as in the case of the eariler lakelet of that name. The outlet stream was marginal as far south as the northeast base of the hill, but there the waters passed onto the ice, on which they continued until the notch was reached, as shown by the absence of erosional or depositional features in the intervening area.

That there was no outlet over the divide south of Massapoag Pond, which lies some two miles west of Rattlesnake Hill, is shown by the fact that the rock-floor is from ten to twenty feet or more lower than at the Rattlesnake Hill outlet, and as much below the level of the East Sharon and Stoughton Plains, the highest of which it could not, therefore, have controlled. The field evidence, moreover shows that the Massapoag valley was occupied by ice until a late stage in the history of the Stoughton Bay region.

Stoughton lakelet.—This is by far the largest of the lakelets in the Stoughton Bay region, and receives its name from the town of Stoughton which is located in the middle of its area. Like the East Sharon lakelet, it was compound, being composed of a larger water body at the north and a smaller one at the south, the two being apparently connected by a narrow channel along the eastern margin in the vicinity of Stoughton. Like the East Sharon lake, it was also located, at least so far as the northern or main portion is concerned, at the termination of a rock hill projecting between two converging valleys in which the ice still remained.

The breadth of the northern portion of the lake from north to south was about one and one-half miles, and from east to west about one and one-quarter miles. The southern portion of the lake was more irregular. From east to west it measured somewhat over a mile in length, but it was less than half a mile in width.

In the northern half of the lakelet the broad Stoughton plains were deposited. While in a general way these plains present a uniform upper limit, the plain was in many places never built up to a

perfectly smooth surface, but is characterized by broad, gentle undulations, merging into kettles about the margins. Some parts, however, are as flat as a floor. In the southern half of the lakelet the plains are generally quite broken, though occasional flat-topped areas exist. The margins of the plains nearest the valleys present in both areas the same gradational type as the East Sharon plains.

The natural outlet of the Stoughton lakelet would at first sight appear to have been southward along the valley followed by the railroad, or along the similar valley half a mile farther east. The altitude of these outlets in each instance, however, is less than 200 feet, while the flat tops of the sand plains, which probably indicate the approximate level of the water of the lake, is 250 feet, or the same as that of the Rattlesnake Hill and East Sharon deposits. It seems clear, therefore, that the southward valleys mentioned were still blocked by the ice. The elevations of the Stoughton plains, corresponding as they do with that of the Rattlesnake Hill outlet, suggest that it was through this notch that the water passed on to the south. To do this it must have crossed the tongue of ice still occupying the valley north of Ames Pond. An examination of the locality seems to show beyond reasonable doubt that this was in fact the case, the waters crossing just north of the road leading eastward from near Dry Pond. The waters in passing deposited much material on the ice, which, on the melting of the latter, was left as an irregular belt of sands, gravels, etc., across the valley at the point indicated, and practically connecting the Stoughton with the East Sharon plains.

LATER OR SPRINGDALE STAGES.

Elm Street lakelet.—This lakelet came into existence after the ice-margin had melted back to a point a mile or more to the west of the position it occupied during the deposition of the Stoughton plains. The lakelet proper was about three-quarters of a mile wide from north to south, and a mile from east to west. In it was deposited the typical flat-topped plains traversed by Elm and Water Streets about a mile southwest of Stoughton. Its upper surface stands at an elevation of 210 feet, and the plain is bounded on the northeast, north, and west by sharp ice-contact slopes, while on the east and south it slopes off into rolling deposits, apparently quite distinct from

ordinary fore-set slopes, and probably representing deposits along the subaqueous ice-wedge, afterward let down as irregular gradational masses, as explained in the case of the East Sharon plains.

The altitudes of the upper limit of the flat-top deposits indicates that the Rattlesnake Hill outlet had been abandoned, and that a newer and lower outlet to the south had been opened up through the valley occupied by Ames Pond at a level of about 210 feet. The ice had not entirely left the valley, a narrow tongue still remaining in the center, along both sides of which, as indicated by terraces with ice-contact slopes toward the valley, outflows took place. On the west side the water followed straight through the valley, but on the east side a portion passed off to the eastward by sub-outlets through notches located respectively near where the highway crosses the pond and just above the south end of the pond.

West Stoughton lakelet.—The West Stoughton lakelet was a body of water one and one-half miles long and one-half a mile wide, extending from Springdale on the north to a point about a mile west of Stoughton on the south. The plain which now marks its position, though fairly flat in places, is much more broken than most of the other plains described, presenting in many places rolling and kettle topography characteristic of deposition open and around more or less detached sheets or blocks of ice. Fine ice-contact slopes extend all the way around the edge from West Stoughton to Springdale, marking the margin of the ice, still occupying the center of the valley.

The elevation of the surface of the West Stoughton plains is from 190 to 200 feet. It seems to have been formed at a slightly later period than the Elm Street plain. The lower altitude of its surface is probably due to the fact that the ice in the depression now occupied by Ames Pond (artificial) had finally disappeared, opening up an outlet a few feet lower than that existing at the time the Elm Street plain was formed. The surplus waters probably escaped through the main and two sub-outlets in the vicinity of Ames Pond as in the case of the Elm Street plain.

Closing stages.—Within the limits of the Stoughton Bay area there are no records of Lake Neponset later than the stage marked by the deposition of the low level plains just described, unless certain unimportant irregular deposits occurring in the center of the valley

are regarded as marking the final passing away of the ice. The ice already reduced to a mere line along the center of the valley could have remained but a short time, and, as the later outlets appear to have been to the north, no further stages of the lake are recorded.

RETREATAL CONDITIONS.

Absence of ice-movement.—That ice-movement had ceased before the opening of the lake history of the Stoughton Bay area is clear from the character and distribution of the deposits laid down. Nowhere in the region are there any deposits of the nature of moraines, such as would have been formed at the front of a living ice-sheet. This applies both to the uplands and to the valleys, which are alike free from till accumulations formed either along a general ice-front or at the terminations of valley ice-tongues.

The form and structure of the stratified deposits also fail to show any forward movement of the ice-bodies, along the margins of which they were laid down. Folding and faulting of a nature indicating thrusts are absent in all exposures which have been seen, and the ice-contact slopes are practically free from till accumulations, such as would have been formed if the ice had possessed sufficient motion to bring fresh materials to the front. The topographic forms are always those which would result from a receding ice-margin, never from an advancing one. The gradational deposits described on pp. 185, 186 are especially significant in this connection.

The strongest evidence, however, is from the distribution of the deposits, which, as has been described, form relatively narrow and successive strips along the sides of the valleys, showing conclusively, when examined as a whole, that the ice-shrinkage was not from south to north, or any other fixed direction, but always away from the valley sides. At the latest recorded stage, as shown by the surrounding deposits, only a narrow strip of ice remained along the center (Fig. 1). Neither this nor the earlier and wider masses possessed the straight or gently curving outlines characteristic of living ice-tongues, but were marked by all the sinuosities and irregularities of an irregularly melting stagnant ice-margin.

Drainage of the ice-sheet.—The highest stratified deposits of Stoughton Bay are the Rattlesnake Hill, East Sharon, and Stoughton

plains, which were deposited in standing water at an altitude of 250 feet. These plains have an aggregate area of at least five square miles, and a probable average thickness of 75 feet. Certain reasons have already been given (pp. 183, 184) why these deposits cannot be regarded as derived from the surrounding uplands, but the most conclusive argument is their immense bulk, considered in connection with the absence of erosion features on the surrounding uplands. That the material came from the ice, therefore, there can be no doubt. The question then is: Were they deposited by subglacial or by superglacial streams?

Half a mile southeast of East Sharon the plains, which here consist of sands and of gravels with pebbles up to several inches in diameter, stand at an altitude of 245 feet, or over 100 feet above the valleys on the east, north, and west, across which the materials must have been borne. If the gravels were transported by subglacial streams, they must have been suddenly lifted a distance of 100 feet. To move a pebble 2 inches in diameter along a level bottom requires a current with a velocity of 2.8 feet per second; to lift it upward requires a velocity of about 3 feet per second. This would correspond to an upward pressure along the assumed ice-tunnel across the valley to the north of 43 pounds to the square inch, and to indicate a head of 2 feet per mile in a straight conduit like that of a circular pipe 6 feet in diameter. In a conduit with the many irregularities of a glacial tunnel the head would probably have to be 10 per cent. greater, or approximately 3¼ feet per mile, in order to give the observed velocity. Slightly lower figures would be given by larger conduits. Such a head could be found at a distance of many miles to the northwest. In living glaciers subglacial streams may possibly exist for considerable periods of time, but it seems beyond the ground of probability that a subglacial stream, with the pressure indicated, could continue over hill and valley for long distances beneath the stagnant ice-sheet without finding a passage for the more ready escape of its waters.

The temperature of a subglacial stream is always, according to observations, slightly above the freezing-point. The corrosive action of a stream, with the velocity and pressure indicated, would rapidly eat the roof of its tunnel, until during a somewhat extended period,

such as would be required for the upbuilding of extensive plains like those of the Stoughton Bay area, a base-level was reached. In crossing a valley the roof of the tunnel would be at least as high as the median height of the valley walls on the up-stream and down-stream sides. The motion of the water would be mainly superficial, and the lower or slack-water portion of the tunnel in the valley or depression would become filled to grade with deposits, which would eventually be left as an immense esker. No deposits of such a character occur in connection with the plains in this region.

In case of the plains of the Stoughton Bay area, there can be no doubt that the streams supplying the material were englacial or superglacial. Of the two, superglacial streams are the more probable. It is clear that there was a connection across the ice between the Stoughton and East Sharon plains, while the waters from both flowed a short distance over the ice in their passage through the Rattlesnake Hill outlet. If superglacial drainage existed at one point, it is likely to have existed at several, and, in the absence of all evidences of subglacial drainage, can reasonably be accepted as the predominant type. It is not assumed that subglacial drainage was not common in other regions, nor that it did not exist to some extent in the region now under discussion; but it played little or no part in the upbuilding of the plains.

Inception of lakelets.—In an earlier paragraph it has been pointed out that there is every reason to believe that the ice had become stagnant before the first of the lakelets of the Stoughton Bay area came into existence, and it is probable that all movement had ceased while the entire surface of the region was still covered by the ice. As the melting of this stagnant ice-field went on, the hilltops began to appear, and the superglacial drainage was obliged to seek the notches for outlets. Seemingly, the first pass to be uncovered was the one immediately west of Rattlesnake Hill, at an altitude of approximately 325 feet; but it appears to have been so situated that it was not available to any of the superglacial streams, for an examination of the ground shows that there was no outflow of water through this pass. Following this, the next to be laid bare as the melting progressed must have been the notch immediately east of Rattlesnake Hill, at an altitude of 250 feet. This is the outlet which is known as the Rattlesnake Hill outlet.

Lakelets of the earlier stages.—The position of the ice-front at the beginning of the flow through the outlet was very near the crest of the pass, as indicated by the distribution of the plains. Later, however, the ice drew back slightly, while farther north it receded at the same time from the valley walls sufficiently to bring into existence the East Sharon lakelet on the west side of the valley and the Stoughton lakelet on the east. Ice-masses still occupied the Massapoag and Ames Pond valleys, and the two southward-leading valleys southeast of Stoughton, leaving the Rattlesnake Hill notch as the only available passage to the south. The outlets of both lakelets were through this pass, to reach which the drainage of both, as has been explained, passed over the ice itself for a short distance.

Opening of the Ames Pond outlet.—The earlier or high-level stages of the Stoughton Bay lakelets were brought to a close when, by the shrinking away of the ice from the retaining hillsides, lower outlets were opened through the valley of Ames Pond. This valley is marked on both sides by terraces exhibiting ice-contact faces on the sides nearest the pond, constituting, in fact, true kame or morainal terraces—a feature not often recognized in eastern Massachusetts. From these it is evident that an ice-tongue still remained in the middle of the valley. This was at first possibly connected with the larger remnant of the ice farther north in the valley, but the melting of the ice, which had previously proceeded slowly by ordinary surface ablation, now probably went on with much greater rapidity, owing to the action of running water on both sides of the valley mass. This rapidly cut away the ice, already greatly reduced by the stream crossing from the Stoughton to the East Sharon lakelet, with the result that the Ames Pond mass was early separated into an independent block.

Lakelets of the later stages.—The Elm Street lakelet was the first of the lower-level bodies to be formed, and the waters found outlet along both sides of the Ames Pond block, forming the kame terrace deposits mentioned. The waters in part passed out from the valley by a bowlder-strewn gorge through granite ledges at the head of the bay just southeast of the highway across the pond, in part by the wider, sand-filled valley between rock hills just above the lower end of the pond, and in part directly southward along the main valley.

Following the Elm Street, the West Stoughton lakelet was formed. By this time the Ames Pond block had become much contracted, or had entirely disappeared, affording an outlet, from 10 to 20 feet lower than the earlier, through the valley now occupied by the pond. These later waters carried little sand, and are represented, therefore, not by deposits, but by their erosive action. The faces of the terraces of the valleys were shaped in places by these waters, but in the main they are of the nature of ice-contact slopes.

CONCLUSIONS.

The results of the study of the Stoughton Bay area, in so far as they apply to retreatal conditions, prove: (1) that in this area the ice had become stagnant before the inception of the lakelets, and remained so throughout their history; (2) that the ice, previous to the emergence of the hills through its surface, was reduced almost entirely by superficial ablation; (3) that the subsequent melting was most rapid along the margins of the projecting land masses, because of the radiation of heat from them and the concentration of drainage along their borders; and (4) that the shrinkage continued to be outward in all directions from the exposed land masses, until the ice was reduced to narrow lines along the deeper valleys, and finally disappeared essentially simultaneously from all portions of the area.

APPLICATIONS.

Extent of glacial lakes.—Hitherto, in the discussion of glacial lakes in eastern Massachusetts, as was pointed out in the introduction, it has been assumed that the ice retreated with a rather definite and regular margin, in front of which extensive bodies of water accumulated in the northward-sloping valleys. While the observations of the writer have not been sufficiently extended to discuss in detail the conditions in other lakes, it has appeared almost certain from reconnaissance studies that the size of the open water bodies in the various lakes at any given time were much smaller than has usually been supposed, and that the marginal lakelets were very numerous, and definite and regular margins relatively rare, the ice having disappeared, in many instances, in the same manner as in the Stoughton area. Which type of retreat prevailed can be determined

only by careful field work, though the facts now at hand seem to indicate that the mode of retreat discussed in the present paper is the most common.

Conditions in southeastern Massachusetts.—A study of the numerous, and often very large, kettle depressions in the stratified drift plains south of Middleboro, and at various other points in Plymouth county in southeastern Massachusetts, shows that throughout large areas in this part of the state extensive masses of stagnant ice existed during the final disappearance of the ice. How broad a belt of such ice existed at any one time or place cannot be readily determined, but in general the belt of no motion was probably not over ten or twenty miles in width, as more or less indefinite morainal bands indicating active ice-movements are found at intervals across the area, while occasionally more pronounced deposits occur.

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RELATIONS OF GRAVEL DEPOSITS IN THE NORTHERN PART OF GLACIAL LAKE CHARLES, MASSACHUSETTS.

INTRODUCTION.

AMONG the most impressive features of the glacial deposits in eastern Massachusetts is the great abundance of sandplains, which occur by scores in all the large valleys. The characteristic flat surfaces, lobate fronts, steep or kettled ice-contact slopes, and tributary eskers testify to the formation of the plains as deltas in glacial lakes, through transportation of the sand and gravel from the ice in which it was incorporated by powerful glacial streams flowing either upon or beneath the ice, and deposition in standing water along the glacier front. In association with the true sandplains are areas of kames, eskers, and other irregular deposits varying from mere patches of gravel to tracts several square miles in extent. At intervals during a period of two or three years the writer has had opportunity to study in detail the sands and gravels within a certain limited area, and takes this opportunity to give a few of his results, hoping they may throw some additional light upon the glacial-lacustrine history of the region.

LAKE CHARLES.

Lake Charles is the name given to the lake, or series of lakelets, which occupied the valley of the Charles River during the decay of the latest or Wisconsin ice-sheet.[1] The region drained by the river embraces portions of the counties of Suffolk, Norfolk, Worcester, and Middlesex, and is covered by the Boston, Framingham, Dedham, Franklin, and Blackstone topographic sheets. All portions of the valley are crowded by thick deposits of sand and gravel, among which flat sandplains are conspicuous, wave-cut shore lines have been occasionally noted, and on the east and south sides of the basin a num-

[1] W. O. CROSBY AND A. W. GRABAU, *American Geologist*, Vol. XVII (1896), No. 2, pp. 128–30; F. G. CLAPP, "Geological History of the Charles River," *Technological Quarterly*, Vol. XIV (1901), No. 3, pp. 171–201; No. 4, pp. 255–69; and *American Geologist*, Vol. XXIX (1902), pp. 218–33.

ber of well-defined lake outlets are known, each of which, as a rule, corresponds in level with the upper surfaces of a particular series of plains. Moreover, a study of the individual plains shows that a number of them often reach approximately to a common elevation, and, with few exceptions, they may be classified into one of several groups distinguished by their different levels. The elevations of the most abundant of these—not including those near sea-level—have been found to be approximately 150, 170, 200, and 270 feet in elevation, although local groups and isolated plains occasionally occur at intermediate levels. A fact thought to be of considerable significance is that plains having a common elevation are distributed over very wide areas. Deltas of the 170-foot series not only are known north and south of the Dover highlands and in the adjacent Neponset valley, but are very abundant across the divide of the Sudbury River in the vicinity of Cochituate, and even far down the valleys of the Sudbury and Concord Rivers. The widespread distribution of plains of the same general elevation at first appears to indicate the presence in the region of a large open body of water, which with successive retreats of the ice-margin, opening outlets for the lake at consecutive lower levels, allowed the water to fall repeatedly to the next stage below. Recent studies by Mr. M. L. Fuller in the Neponset basin indicate, however, that in that region there was no such simple sequence of events; and the present writer, working independently, finds evidence in Lake Charles indicating that here too the open lake hypothesis can be accepted only in part.

DESCRIPTION OF THE REGION.

The location of the main region under consideration in the present paper is shown in Fig. 1. In a general way, it includes that portion of the Charles River basin lying south of the Boston & Albany Railroad in Newton and north of the Dedham and Dover highlands. More definitely, it is that part of the drainage basin of the present Charles River lying within that of the preglacial Charles. The portions of the valley lying north of the Boston & Albany Railroad, and those east of the Brookline and West Roxbury highlands, are not included, being within the limits of what has been designated Lake Shawmut—a glacial lake corresponding with later stages of the ice-retreat.

Topography.—A glance at the topographic map shows that the region may conveniently be divided into the following subdivisions: the Western highlands, the Dover and Dedham highlands, the Brookline and West Roxbury highlands, the Needham-Waltham valley,

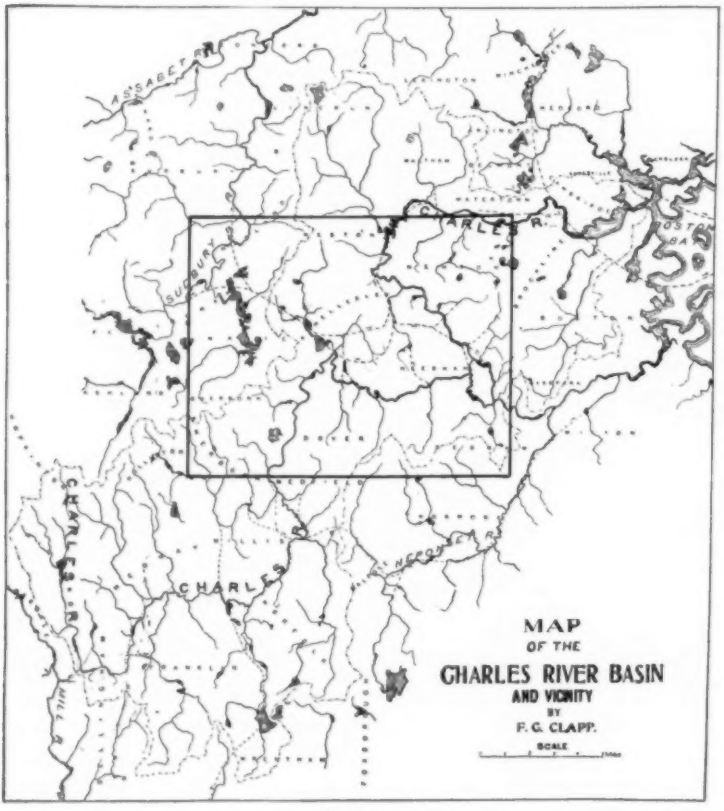

FIG. 1.

and the regions intermediate between uplands and lowlands, the last division consisting of the greater part of the towns of Newton, Needham, and Wellesley. Another feature of importance is the broad area of modified drift extending westward from Wellesley to the Sudbury River, and overlying the site of a broad preglacial

valley 100 feet or more below the present surface. This valley—the ancient outlet for the Sudbury valley drainage, is supposed to continue beneath Wellesley to the valley of Rosemary Brook, and thence northward to the present Charles River at Riverside. The broad marshy area east of Needham, in which the bed-rock surface is known to lie at a considerable depth below sea-level, was probably occupied by a tributary of the Charles which entered the main river just north of Highlandville. The valley between South Natick and Dedham contained no single preglacial stream. The largest unbroken upland region is the broad band extending westward from the Neponset River across Dedham, Westwood, Dover, and Sherborn, which in preglacial times separated the lowlands on the north and south into two distinct drainage systems, since united along the course of the Charles River.

DESCRIPTION OF THE DEPOSITS.

In a provisional classification we may recognize the following types of deposits as occurring in this portion of Lake Charles:

1. Flat-topped delta-fans—typical gravel plains—the level of which varies but a few feet in a single plain. These deltas almost invariably have a beautiful ice-contact slope, but the common lobate front may or may not be developed. For this class of deposits the common name of "sandplain" is used, although the plains considered consist largely of gravel.

2. Kettle plains, or deposits with a definite maximum elevation, but so broken up by kettle-holes as to have little semblance to plains. In origin, they differ from true sandplains only in having been formed among crowded ice-masses.

3. Eskers, or deposits of glacial streams. These are often conspicuously tributary to deltas.

4. Irregular deposits of gravel along the sides of valleys, usually consisting of great numbers of small hills or kames densely crowded together, for which the name "moraine-terrace" is sometimes used.

5. Kames—the name comprising all small, irregular hills of sand and gravel not included under (3) or (4).

6. Thin coatings or undulating deposits of gravel, apparently having no definite relations.

In the present study particular attention is given to the first three types.

SANDPLAINS.

Although in ascertaining the elevations of the plains the writer has not had opportunity to do any leveling, yet from the excellent contouring on the new Boston sheet, and in some instances by the aid of the older topographic maps, the approximate elevations have been interpreted in the field. Within the immediate area under consideration twenty-five typical plains have been studied, which are here named, with their approximate heights above tide. The distribution of the plains and their associated eskers is shown in Fig. 2.

1. Newtonville plain, 150 feet.
2. Newton Highlands plain, 150 feet.
3. Newton Center plain, 150 feet.
4. Winchester Hill plain, 150 feet.
5. Nahantan plain, 150 feet.
6. Cow Island plain, 140 feet.
7. West Roxbury plain, 140 feet.
8. Dedham Island plain, 150 feet.
9. Lower Falls plain, 150 feet.
10. Waban plain, 150 feet.
11. Wellesley plain, 150 feet.
12. Needham plain, 170 feet.
13. Birds Hill plain, 190 feet.
14. Dedham plain, 120 feet.
15. Wigwam plain, 120 feet.
16. Islington plain, 120 feet.
17. Pegan plain, 160 feet.
18. Noanet plain, 150 feet.
19. Cedar Hill plain, 270 feet.
20. South Natick plain, 120 feet.
21. Trout Brook plain, 100 feet.
22. Greendale plain, 100 feet.
23. Riverside plain, 60 feet.
24. Auburndale plain, 70 feet.
25. Newtonville plain No. 2, 80 feet.

Where the plains slope appreciably away from the ice-contact the elevation of the outer edge is taken, as representing most closely the true water-level. Most of them slope slightly, the difference in elevation sometimes amounting to as much as 20 feet, which makes it evident that plains having elevations given as 150 feet and others as 170 feet might have been formed as deltas in the same body of water. That such was probably *not* the case will be shown below.

In addition to the plains already enumerated, several exceptionally fine developments outside the Needham area have been visited in this connection. The most important of these are as follows:

26. North Wellesley plain, 170 feet.
27. Pickerel Pond plain, 170 feet.
28. Cochituate plain, 170 feet.
29. South Framingham plain, 170 feet.
30. Medfield Junction plain, 170 feet.

A comparison of the elevations of the thirty deltas shows that twelve of the number have an elevation of 140–50 feet, six of them of

170 feet, four of 120 feet, three of 60–80 feet, two of 100 feet, one of 160 feet, one of 190 feet, and one of 270 feet. All below 120 feet were deposited during the Lake Shawmut stages. The remaining twenty-five will be described somewhat in detail.

FIG. 2.—Distribution of principal eskers and sandplains. The dash line shows the boundary of Fig. 3.

NEWTONVILLE-WEST ROXBURY SANDPLAIN ESKER SYSTEM.

This series of deposits is situated entirely on the east side of the Charles River, and consists of a continuous series of alternating plains and eskers extending from the northern end of the Newtonville

esker, one-half mile south of the Boston & Albany Railroad, across Newton to the frontal lobes of the Dedham Island and West Roxbury sandplains—a total distance of about six miles.

Newtonville esker and plain.—The classical delta known as the Newtonville sand plain, which has been described by Davis and Gulliver,[1] lies fully a mile south of the railroad, about half-way between Newtonville and Newton Center. It has an elevation of 150 feet, and averages fully three-fourths of a mile long and half a mile wide, occupying nearly the whole breadth of the valley of Laundry Brook. Several preglacial knobs rise through the plain, and to the east it rests against a low rock hill capped by a drumlin rising to an elevation of over 300 feet; on the north and west sides are characteristic ice-contact slopes; while a short stretch on the south forms good frontal lobes. Viewed from any standpoint, the deposit is a typical sand-delta, and well merits even more careful study than it has received. A large excavation on Commonwealth Avenue gives an unexcelled opportunity for viewing its internal structure.

The feeding stream of the delta is represented by the Newtonville esker, which first appears as it rises from beneath the lower and more recent plain at Newtonville, about three-fourths of a mile north of its junction with the sand plain. On both sides are large areas of densely crowded kames and kettles, with which the esker in places becomes somewhat confused.

Southwest of the plain there is also a small kame area. Unlike the southeast side, which has good frontal slopes, the southwest corner immediately south of Commonwealth Avenue breaks up into kames and kettles, which are composed of very coarse gravel, abounding in bowlders up to several feet in diameter. Within four hundred feet a further change takes place, by which the irregular hills become shaped into a typical esker, bounded on both sides by kames, and running in the direction of the Newton Highlands plain. Before reaching this there is a short break, due to a swamp, but the parallelism of the esker to the rock hill on the east, the close similarity between the levels of the two plains, and the apparently perfect

[1] W. M. Davis, "The Subglacial Origin of Certain Eskers," *Proc. B. S. N. H.*: Vol. XXV (1892), pp. 477–99; F. P. Gulliver, "The Newtonville Sand Plain," Journal of Geology, Vol. I (1893), pp. 803–12.

topographic relationship indicate strongly that the esker stream was the feeder of the Newton Highlands delta.

Newton Highlands plain.—This plain, somewhat irregular in shape, extends a little over a mile in an east-and-west direction, and half a mile in its greatest breadth north and south. Like the Newtonville plain, it is bounded on the east by a rock hill, has ice-contact slopes on the north and northwest, and frontal lobes on the south; but the ice-contact in this case differs in character from the other by being extremely irregular, and in places much broken up by kettles. On the southwest the fore-sets run against the rock hill south of Eliot Station; on the north and south it is bounded mainly by low, swampy areas. It is for the most part a typical sandplain.

Cook Street esker.—The most interesting feature of the Newton Highlands plain is on the south side, near the Cook Street junction of the New York, New Haven & Hartford with the Boston & Albany Railroad. At this point a small knob of conglomerate rises above the glacial drift, and towards the north and east the fore-sets are broken and irregular, indicating the presence of ice here at the time of their deposition. Directly east of the conglomerate knob and south of Cook Street is a low esker running southward out of the sandplain. Beyond the first road it rises to a height of 30 feet or more above the swamp, and farther south widens to a breadth of at least 500 feet; but within 2,000 feet ends abruptly at a small brook. As this somewhat peculiar esker has been extensively excavated, its internal structure can be easily studied. The south end being in itself something of a delta, the main stream which formed it was probably not *directly* tributary to any plain.

Winchester Hill eskers and plain.—A few hundred feet to the west, however, and holding very definite relations to the small plain west of Winchester Hill, is another esker. Starting half-way up the side of the rock hill south of Eliot Station, it descends fully 40 feet. becoming at once a good-sized ridge, crosses the swamp to the kame field west of Highland Avenue, with which it soon becomes confused, and joins the sandplain at its northwest corner.

The Winchester Hill plain is comparatively small, hardly one-eighth the size of the Newtonville plain, although topographically its relations are somewhat similar; it is bounded on the east by a drumlin,

the remaining three sides being free. Unlike the deltas already described, this plain has no frontal lobes, being surrounded on the north, west, and south by ice-contacts. Both to the south and west are extensive areas of kames and moraine-terrace.

Nahantan plain.—Lying a mile and a half southeast of Winchester Hill, in the midst of a large kame field, is a plain having the same approximate maximum elevation as the surrounding kames and of the associated esker. In extent of isolation it goes a step beyond the Winchester plain, as its surface does not rest at any point against rock or till, and it is entirely surrounded by ice-contacts and kames. As the slope of the Brookline highlands is not over 1,000 feet distant, it is likely that rock exists only a short distance below the surface, and the plain occupies as truly a marginal position as the others mentioned. In the area between this and the Winchester plain are two eskers, which, while they have not been observed to run directly into either plain, are supposed from their positions to mark the streams which carried the water southward between the two lakelets.

The esker running out of the Nahantan plain is better defined in its relations than the ridges similarly situated with reference to the preceding deposits. It quickly attains its individuality, and borders the kame area for nearly half a mile before finally disappearing below the Charles River meadows. One feature well worthy of special note occurs just south of the plain, where there is an enlargement of the esker barely 200 feet across, yet having all the characteristic structural features of the larger plains. South of the terminus of this esker the relations of the eskers of the series are not well defined. Short ridges appear above the flood-plain west and north of Cow Island, and continue from near Spring Street southeastward, crossing Washington Street on the boundary line between Boston and Dedham, beyond which no attempt has been made to trace them. At the southern point of Cow Island is a good junction of the main esker with a ridge which crosses the river from the south.

Cow Island, West Roxbury, and Dedham Island plains.—The elevations of the first two of these are indicated by the map as about 10 feet lower than the other plains of the system. This discrepancy may be real, but is more probably due to difficulty of interpreting the contours on a map of the published scale. In either case, it is believed

that these three plains are of the same height, and were controlled by the level of a single body of water. They are all bounded on the west by steep and irregular ice-contacts, and the West Roxbury and Dedham Island plains rest visibly against preglacial knobs of land. With the Cow Island plain, on the contrary, no till nor rock can be found associated, and several wells drilled at the pumping station on the southeast side of Cow Island prove that the drift is here very thick. In one instance 90 feet of gravel was penetrated before reaching bed-rock.

Conclusions and discussion.—From the foregoing description several characteristics common to the deposits may be formulated:

1. The plains are nearly always marginal—deposited about knobs of rock or till. Conversely, most of the preglacial prominences rising above the valley floor have glacial deposits associated with them. This is probably partly due to the natural sinking of the decaying ice masses into the valleys, and in part to the principle that the heat reflected from rock masses accelerates the melting of the ice immediately surrounding them, forming hundreds of small marginal lakelets, throughout the decaying zone of the ice-sheet.

2. The plains without exception have a definite ice-contact slope, which in several instances entirely surrounds them, except on the sides which are bounded by higher land. This feature indicates that some of the lakelets became entirely filled by gravel, forcing further deposits to accumulate in quantity along the channels of glacial streams or in superglacial lakelets.

3. Where typically developed, the deltas are associated with feeding eskers on the north, and with effluent eskers on the south. Such a relation can only mean that the glacial lakes, like bodies of water on the present land surface, had both inflowing and outflowing streams, the latter carrying off the surplus water and providing a transporting and depositing agent for the excess of gravel. This is in accordance with what has been observed on the Malaspina glacier.[1] The controversy in regard to the superglacial or subglacial origin of eskers will not be entered here, but the writer believes there is evidence that eskers of both classes exist in the region, and that

[1] I. C. RUSSELL, "Expedition to Mt. St. Elias, Alaska," *National Geographical Magazine*, Vol. III, pp. 106–8.

by careful study of the individual cases their differences in origin can be detected.

4. The elevation of all the plains of the system is very nearly or quite uniform, at about 150 feet above tide. Thus, notwithstanding the supposition that there can have been no large open lake in the region, there was certainly some connection between the lakelets adequate to maintain the water at a common level. The remnants of the decaying ice-sheet consisted of stagnant valley-blocks much broken up, the whole mass saturated with water, which was maintained at a uniform level consequent on some factor outside the Needham area. Into this basin were discharged torrents of water, which carried the gravels and deposited them upon, beneath, and between the ice-masses. This view is satisfied both by the superglacial and subglacial theories of eskers, and further corroborates the supposition that in this area there are examples of both classes.

As the difference in elevation between the different plains of the series can not be more than a few feet, it is evident that in the waters of the lakelets themselves or below their level there can have been but little current. Notwithstanding this, it is known that water-worn bowlders of considerable size are abundant in many of the eskers and associated deposits, indicating a very powerful current. The most probable explanation, already alluded to, is that to the main superglacial or subglacial rivers were tributary many side streams which discharged into them from higher levels on the ice or surrounding land. The extensive kames and moraine-terraces are best explained, as shown by Fuller in the case of Lake Neponset, by supposing them to have been deposited upon masses of ice sometimes of considerable thickness, having a front sloping outward beneath the lacustrine waters.

The probable conditions existing during this stage are indicated in Fig. 3, in which the lakelets are represented by the dotted portions and the stagnant remnants of the ice-sheet by shading. The regions covered by a combination of these patterns usually correspond in position with large areas of moraine-terrace, and were at this time ice-tongues overlain by considerable depths of water, in which the superglacial and subglacial gravels were deposited. Glacial streams, so far as traceable, are shown by heavy black lines.

Their most striking feature is that they are conspicuously divided into two series, one following in a general way each side of the main valley and known to have connected with the other only at a single

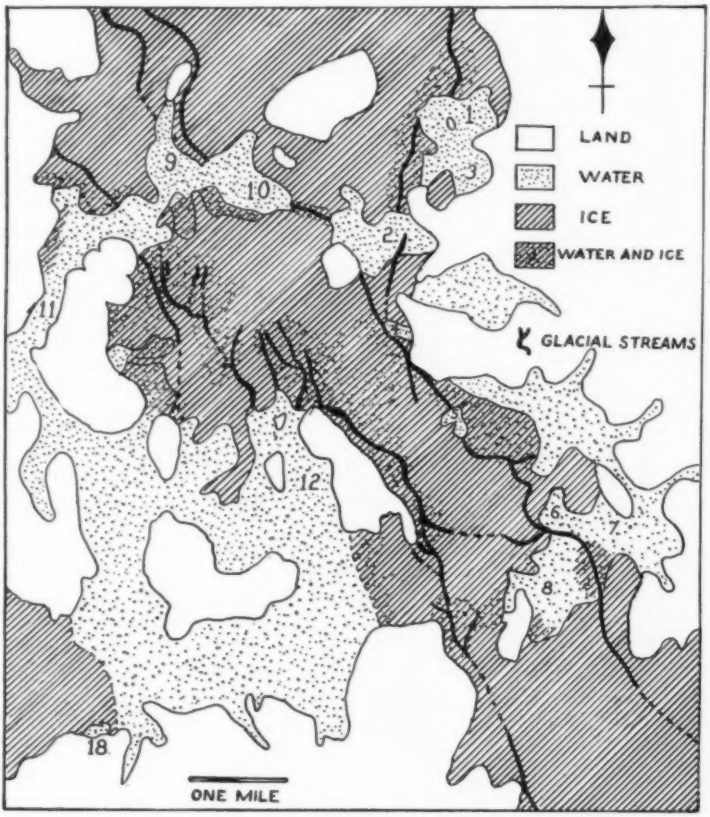

FIG. 3.—Probable conditions during the 140–170-foot stage of the glacial lakelets. (Numbers show locations of plains, and correspond with list given in the text.)

point. It is probable, however, that there were other connections which have not been preserved in the deposits. A second noticeable feature in the eastern series is the confluence at the Winchester Hill lakelet of two rivers, both of which have been traced for some dis-

tance outside the map, and were apparently the only main streams draining the triangular area which they include.

THE NEEDHAM-FRAMINGHAM SYSTEM OF PLAINS.

For convenience of discussion this designation is applied to the group of plains lying between Needham and Framingham, having, in addition to a common elevation of approximately 170 feet, most of the characteristics of the preceding group. These deposits cover an area beside which the Newtonville-West Roxbury area appears insignificant; yet, as the writer has had little opportunity to study them in detail, they will be dismissed with a few remarks. Belonging to the group are at least six plains—the Framingham, Cochituate, Pickerel Pond, North Wellesley, and Needham plains. All have good ice-contact slopes, most of them on certain sides only; but one plain, that lying east of Pickerel Pond between Wellesley and Cochituate, is entirely surrounded by characteristic steep and kettled slopes. This plain, like that forming Cow Island, is the only member of its group not resting against the rock sides of the valley, and, like Cow Island, is supposed to overlie a buried preglacial gorge.

The most conspicuous topographic characteristic of this region is the abundance of kettle-holes, often occupied by ponds. Lake Cochituate, Dudley, Pickerel, Mud, Jennings', and Morse's ponds and Lake Waban are all kettle-ponds, overlying the course of the preglacial Charles River. Between, around, and upon the ice-blocks gravels were deposited, their mode of origin being demonstrated by their kettled character. The proportionate area of kames to kettles is much larger than in the deposits farther east, and the kettles are more isolated. Plains having in general the same elevation extend far down the valleys of the Sudbury and Concord Rivers; thus emphasizing the suggestion that in the Sudbury valley there were at that time fairly open bodies of water.

Needham plain.—This is the largest and most typical plain in the group. Hemmed in on east and west by rock hills, it is bounded on the north by a deep preglacial valley, in which the ice lingered and gave rise to deep kettles, extensive moraine-terraces, kames, and eskers. Three or more eskers, with relations suggesting a superglacial mode of origin, enter the plain from the north. Its southern

side shows a beautiful lobate front, which, together with the absence of kettles and the scarcity of modified drift immediately to the south, indicates that in that direction was an open lakelet three to four miles in extent. The overflowing water, reinforced by the drainage from an extensive area to the west, found its outlet eastward through a large superglacial or marginal stream.

Lower Falls, Wellesley Hills, and Waban plains.—These are all about 150 feet in elevation, and the first two originally formed a single plain. Extending in an irregular line from near Rice Crossing north of Wellesley Hills to Newton Lower Falls, and thence to the high morainic hills east of Riverside, is a kettled and kamey ice-contact nearly three miles in length. Large kettles south and east of the Lower Falls indicate that the glacier to the north was almost connected with the decaying ice-blocks on the southeast side of the plain; but that it was not quite continuous is indicated by consideration of the fact that the slopes on both sides of the river are erosion slopes, in which artificial excavations show nearly horizontal stratification, probably once continuous across the valley. The Waban plain, lying closely adjacent to the Lower Falls plain on the east, was formed by the Auburndale esker stream.[1] It is bounded on the north and south by ice-contacts, is much broken up by kettle-holes, and might properly have been classified with the Newtonville-West Roxbury group, with which it is closely connected.

Other plains of the series.—In the valleys east and west of Dover are two or more small plains at approximately the same elevation, which are shown by ice-contacts on their valley sides to be deposits of small marginal embayments. Plains of the Newtonville-West Roxbury type occur in the Medfield-Medway basin of the Charles River, and also in the Neponset valley. The uniformity of elevation over such a wide area strongly suggests dependence upon some lake-outlet east of the Neponset valley. No systematic search for such an eastern outlet has been made in the field, but it is known that in the southern watersheds of the Charles and Neponset Rivers there is no pass lower than 200 feet above tide.

[1] J. B. WOODWORTH, "Some Typical Eskers of Southern New England," *Proceedings of the Boston Society of Natural History*, Vol. XXVI, pp. 197–220; W. M. DAVIS, "The Subglacial Origin of Certain Eskers," *ibid.*, Vol. XXV, pp. 477–99.

The perfect ice-contact slope along the Boston & Albany Railroad east of Wellesley Hills, together with the absence of any flat-topped deposits rising higher than 90 feet, throughout the area to the northward, and likewise from the entire region east of the Brookline and West Roxbury highlands, proves that the northern part of the Boston basin was then occupied by the still little-decayed ice-sheet, an arm of which extended up the Neponset valley as far as Norwood.

PLAINS OF OTHER LEVELS.

Cedar Hill lakelet.—There still remain to be mentioned several important plains at levels different from any heretofore described. One of these plains occurs on the divide between Noanet and Mine Brooks in Dover. It lies at an elevation of 270 feet, and has a tributary esker on the north and frontal slopes on the south. Beginning a short distance south of the plain, and extending to beyond Walpole, a distance of over four miles, is one of the finest eskers in the region, supposed to mark the course of the stream through which this lakelet discharged.

Dedham plains.—In the towns of Dedham and Westwood are several plains having an elevation of about 120 feet. These are flat-topped, are either entirely or nearly surrounded by ice-contacts, have abundant kettles, and are not known to correspond with plains of any other group. Along the valley of the Charles River, between Dedham and South Natick, are a number of plains at elevations of 100 to 120 feet, which may belong to the same stage. Below this elevation all the plains are confined to the Lake Shawmut area, the western limit of which is marked by flat 90-foot deposits north of the ice-contact at Riverside and Newton Lower Falls, and which extend eastward throughout the Boston basin, where they are recognized at all elevations down to sea-level.

HISTORY OF THE LAKELETS.

The highest known plain in the region, the Cedar Hill plain, has an elevation of 100 feet above the next lower level, and must have been formed at the time of the earliest uncovering of the pass in the Dover highlands, which left a lake irregular in shape covering an area of nearly one square mile, walled on the east and west by rocky hills, and on the north and south largely by ice. The eskers in the

valleys of Noanet and Mine Brooks suggest that this is another instance of a glacial lake having both inflowing and outflowing streams.

The occurrence of so numerous and widely scattered sandplains having a uniform elevation, which, notwithstanding their wide distribution, were evidently formed in merely local lakelets, often resting in part on the ice itself, is best explained by the assumption that the ice was in such a state of decay as to allow a connection between the individual lakelets sufficient to maintain the water at a common level. Such being the case, the general level of the waters at the different stages must have been determined by one of two causes; either, first, by deposition in an arm of the sea, or, second, as was more probable, by topographic features, probably passes between the highlands on the east side of the lower Neponset valley, through which the water escaped to Lake Bouvé,[1] and thence to the sea. The probable explanation for the lack of plains between the 270- and 170-foot levels is the absence of any pass intermediate between these elevations on the northern side of the Blue Hill range. In the southern portion of Lakes Charles and Neponset, where passes of other levels occur, intermediate plains also abound. The relations of ice, land, and water during the 170–150 foot stage are shown in Fig. 2.

This stage of the lakelets existed during the entire time while the outlets remained at this elevation. When the decay of the ice had advanced sufficiently to open a 120-foot outlet north of the Blue Hills, the ponded waters fell to that level. There is no indication that during this time there was any considerable disappearance of the ice in the upper and central portions of the Charles River basin, for in these portions no plains are known below 160 feet. The absence of synchronous plains in the Lake Shawmut area indicates that this was still for the most part ice. By far the greater portion of the 120-foot plains is situated in the town of Dedham, their location being probably due to their favorable position at the head of the Charles River valley glacier. Another view of their origin is that they represent merely a local stage, while the greater portion of the waters stood at a lower level.

[1] A. W. GRABAU, "Lake Bouvé," *Occ. Papers, Boston Society of Natural History*, Vol. IV, part III, pp. 564–600.

CONCLUSIONS.

The most important generalizations to be drawn from this study are as follows:

1. The decay of the ice *in situ* for many miles back from the ice-front—the decaying glacier consisting of a mass of stagnant ice overlain and buried by sheets of water and by extensive deposits of sand and gravel.

2. The more rapid disappearance of the ice on the west than farther east, causing a nearly open lake in parts of the Sudbury valley, while as yet the ice in the lower portions of the Boston basin had not decayed sufficiently to allow the formation of a single sand plain.

3. The interdependence of the water levels of the individual lakelets belonging to each stage, and their correspondence with some common outlet toward the sea.

FREDERICK G. CLAPP.

WASHINGTON, D. C.

THE LEOPARDITE (QUARTZ PORPHYRY) OF NORTH CAROLINA.[1]

INTRODUCTORY STATEMENT.

WHILE engaged, during the past summer, in a study of the granites of North Carolina for the State Survey, opportunity offered for examination in the field of the well-known and interesting rock called "leopardite," which occurs near Charlotte in Mecklenburg county. Knowledge of the occurrence of this rock in the state dates back many years, and brief descriptions of it have been published from time to time by different writers, as noted below in the appended references.

In 1853 Dr. Hunter[2] briefly described, megascopically, the general appearance, including locality, of the leopardite found near Charlotte, Mecklenburg county, North Carolina. He says: "It is noticed by Professor Shepard, under the head of feldspar, as the leopard stone of Charlotte, North Carolina." Professor Shepard regarded it as composed of compact feldspar and quartz spotted by the oxides of iron and manganese. Hunter suggested the propriety of retaining the name "leopardite," for the reason that it is quite characteristic of a rather unique rock. In the same paper the author refers to a second locality in Lincoln county, North Carolina, where leopardite had recently been found. Concerning the character of the rock in Lincoln county, he says: "The pervading stripes are, however, generally finer; and when broken diagonally, it presents a handsome arborescent appearance."

In 1862 Dr. F. A. Genth[3] described the leopardite occurring near Charlotte as a true porphyry, and gave some general results of a microscopical examination of thin sections of the rock, including a chemical analysis. Still a third locality in North Carolina where

[1] Published by permission of the state geologist of North Carolina.

[2] C. L. HUNTER, "Notices of the Rarer Minerals and New Localities in Western North Carolina," *American Journal of Science.*, Vol. XV (1853, 2d ser.), p. 377.

[3] F. A. GENTH, "Contributions to Mineralogy," *ibid.*, Vol. XXXIII (1862, 2d ser.), pp. 197, 198.

leopardite is reported to be found is referred to by Genth, namely, near the Steele mine in Montgomery county.

More recently the leopardite occurring near Charlotte has been noted by Merrill[1] and Lewis[2]. After briefly describing the general appearance of the rock, Professor Merrill makes further statement of its economic value. In connection with his work on the building-stones of North Carolina, Lewis visited the locality to the east of Charlotte, where the leopardite is exposed, and, so far as contained in published accounts of the rock known to me, he was the first to note its true geological occurrence.

Quartz porphyries in association with other closely similar acid volcanic rocks are developed, in places, over the central and the northwestern parts of the state. So far as known at present, the areas of acid volcanic rocks are confined to the volcanic belt which skirts the western margin of the Triassic sandstone in the eastern Piedmont region,[3] and to several of the extreme northwest counties[4] of the state. These rocks show no essential differences, so far as they have been studied, from certain areas of similar ones which occur and are traced at irregular intervals northward along the Atlantic border region of North America as far as Newfoundland.

Of those occurrences in North Carolina, the quartz porphyry found near Charlotte is the only one visited by me that shows the characteristic spotted appearance so suggestive of the name "leopardite." Except for the mottled or spotted appearance produced by rounded black areas of metallic oxides, the Charlotte rock differs but slightly, if at all, in essential characters from quartz porphyries described from other localities. (See table of analyses on p. 223).

[1] GEORGE P. MERRILL, *Stones for Building and Decoration* (New York, 1897), 2d ed., pp. 272, 273.

[2] J. V. LEWIS, *Notes on Building and Ornamental Stone*, First Biennial Report of the State Geologist, N. C. Geological Survey, 1893, p. 102.

[3] GEORGE H. WILLIAMS, "The Distribution of Ancient Volcanic Rocks Along the Eastern Border of North America," JOURNAL OF GEOLOGY, Vol. II (1894), pp. 1–32; J. S. DILLER, "Origin of Paleotrochis," *American Journal of Science*, Vol. VII (1899, 4th ser.), pp. 337–42.

[4] A. KEITH, *Bulletin No. 168*, U. S. Geological Survey, p. 52; *Geologic Atlas of the United States*, "North Carolina-Tennessee, Cranberry Folio," 1903.

LOCATION AND OCCURRENCE.

The leopardite is exposed in a number of small outcrops at Belmont Springs, about one and a half miles east of Charlotte. Beginning on top of the hill, several hundred yards above the spring the rock is traced in outcrops over the surface for a distance of a quarter to a half mile in a north 30° east direction. It forms a true dike, intersecting a medium textured and colored, sheared and crushed,

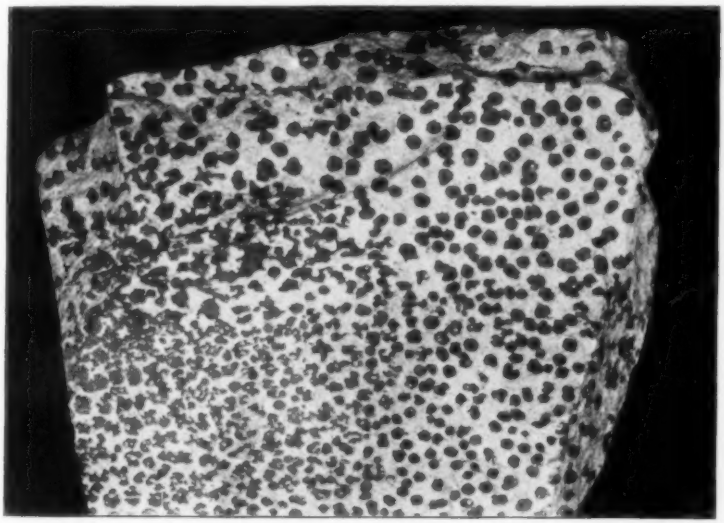

FIG. 1.—View showing the spotted appearance of the rock on a surface broken at right angles to the longer direction of the pencils. Photographed from a hand specimen. (One-half natural size.)

biotite granite; and, so far, as it was possible to determine, the dike nowhere exceeds twenty-five feet in width, with a smaller average cross-section. A small opening in one of the outcrops from which some of the rock has been blasted reveals a sharp contact between the quartz porphyry and the inclosing granite.

MEGASCOPIC DESCRIPTION.

The fresh rock is nearly white, tinged the faintest greenish in places, and penetrated by long parallel streaks or pencils of a dead

black color. When broken at an angle to the direction of the pencils, the rock surface appears spotted with rounded, irregular black points, ranging in size up to a half inch in diameter. At times the roundish points are somewhat irregular and only partially developed, as shown in the lower left half of Fig. 1. These may be crowded close together over the surface, as seen in the figure, or or they may be entirely absent from some areas and irregularly distributed at wide intervals over others, as indicated in Fig. 3. Indeed, the black points are reported to fail entirely in the rock as the dike is traced northward, when the rock assumes a uniformly light color throughout. However, every outcrop and specimen of the rock seen by me contained them.

A section cut parallel to the direction of the pencils presents a surface streaked with long, somewhat irregular, though roughly parallel, black lines, more or less perfect dendritic or fern-like forms (Figs. 2 and 3). I was shown recently a large slab of the rock collected from one of the outcrops since my examination in the summer of 1903, which, for perfection and delicacy of tracery in fern-like forms, was beautiful beyond description. The black streaks or pencils which characterize the rock are composed of a staining of the oxides of manganese and iron.

The rock is cryptocrystalline in texture, breaking with a conchodial fracture, and is intensely hard and tough. Minute quartz crystals of doubly terminated pyramidal faces are distributed through the rock at irregular wide intervals. These are nowhere abundant in the rock, but they are always present to some extent, and consist both of the light-colored and the dark, smoky, vitreous quartz. Indeed, unless carefully examined, the rock would ordinarily be pronounced non-porphyritic in texture, so small and scattering are the porphyritically developed quartzes. Megascopically, porphyritic texture is nowhere particularly emphasized in the rock, but its slight development is best seen on a weathered surface of the stone, where the unaltered quartz crystals, though few in number and widely scattered, contrast more strongly with the weathered surface and appear more conspicuous than in the fresh rock Feldspars are also porphyritically developed, as described below, though the phenocrysts are difficult of differentiation in hand specimens of the rock.

MICROSCOPICAL DESCRIPTION.

In thin sections the rock consists of a holocrystalline groundmass and scattered small porphyritic crystals. Flow-structure is not exhibited in the groundmass, and the phenocrysts indicate no orientation with respect to each other. The groundmass is micro-granitic in structure, though some sections show much of the micro-granophyric structure, with an irregular radial, spherulitic, structure developed in greater or

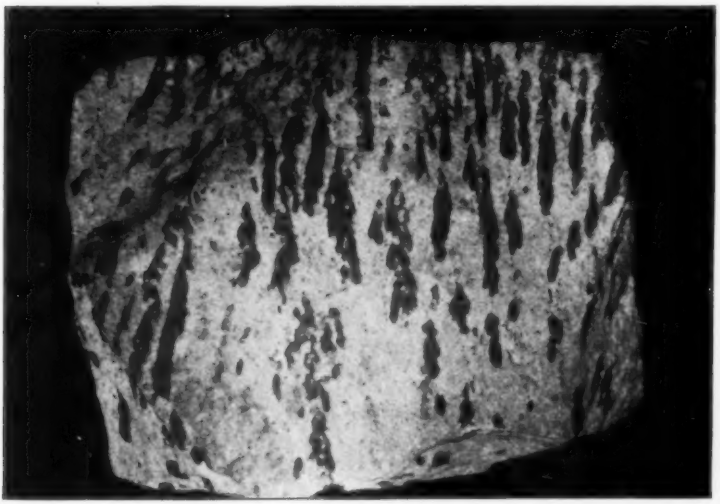

FIG. 2.—View showing approximately parallel black streaks and pencils on rock surface broken parallel to the direction of the pencils. Photographed from hand specimen. (One-half natural size.)

less proportion in all of the sections studied. When they form complete spheres, which is rarely the case, they usually exhibit somewhat irregular ragged peripheries, and further show usually between cross nicols a very indefinite black cross. The form of the grains in the typical micro-granitic areas of the groundmass is sharp and allotriomorphic to partially idiomorphic. The principal groundmass minerals are feldspar and quartz, with much light-colored mica, and an occasional inclusion of prismatic apatite and zircon. Irregular minute grains of iron oxide are scattered through the sections, and stained

areas from manganese and iron oxides, forming the dark spots and pencils in the hand specimens, occur. The thin sections are characterized by the complete absence of ferro-magnesian minerals.

Feldspar is apparently in largest quantity, and is composed of both potash and plagioclase species. Occasional grains of microcline are recognized which show the characteristic microcline twinning. The unstriated feldspar grains so strongly resemble quartz that it is impossible in many cases to distinguish them without the application of optical tests. Optical tests show the plagioclase to be albite—a circumstance entirely confirmed by the chemical analysis of the rock given below in the table of analyses under I, in which only the barest trace of lime is indicated, with soda in large amount and in excess of the potash. Some of the plagioclase exhibits polysynthetic twinning according to the albite law, and at times assumes lath-shaped forms. The feldspar substance is generally fresh, but the individual grains are usually rendered dark by abundant, closely crowded, minute, dark, dust-like particles, the identity of which could not be made out.

Quartz is of the usual kind and presents no noteworthy features, further than its occurrence in small mosaics of interlocking grains, which occupy at times distinct areas in some of the thin sections.

Light-colored mica, tinged a faint yellow, is very generally distributed through the sections, in the form of irregular minute shreds, groups, and aggregated masses, the folia of which are at times imperfectly arranged radially about a common center. A part, at least, of the mica is clearly secondary, while some of it is yet doubtful as to origin, whether primary or secondary. Its general appearance and association in the sections might very well indicate secondary formation for all of it.

Phenocrysts of both quartz and feldspar occur in well-developed idiomorphic forms, usually in rectangular and squarish cross-sections. In the thin sections studied phenocrysts of feldspar are more abundant than quartz; and while the porphyritic texture is poorly developed in the hand specimens, it is very pronounced in the thin sections. The quartz phenocrysts show irregular fractures free from impurities, strained shadows, and occasionally inclose grains of feldspar. The porphyritic feldspars show in part broadly twinned bands of plagio-

clase, and untwinned orthoclase. These are frequently rendered nearly opaque from innumerable, closely crowded, dark inclusions not identifiable, along with minute spangles of colorless mica. Zonal structure is rarely observed, and cleavage is usually wanting. Around the borders of several of the feldspar phenocrysts slight embayments, produced by incipient resorption, are noticeable.

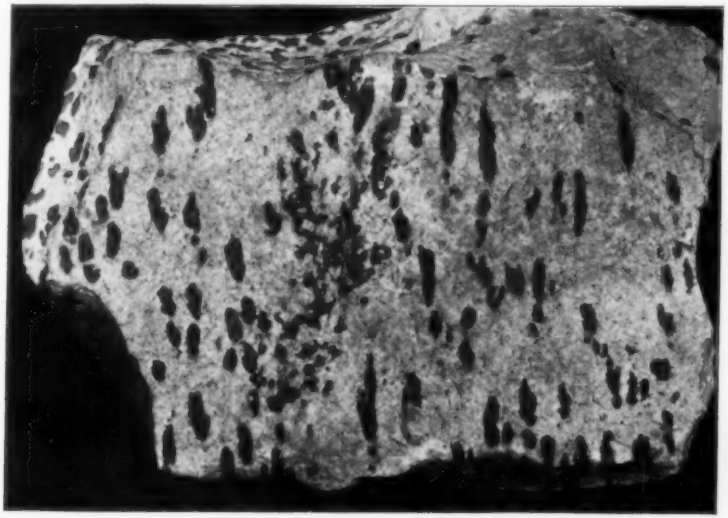

FIG. 3.—View showing partially spotted and partially streaked rock, with tendency toward arborescent form manifested near the middle of the picture. Surface broken at an angle intermediate between that of Figs. 1 and 2. Photographed from hand specimen. One-half natural size.

Several of the sections were so cut as to include areas of the black pencils which characterize the rock, megascopically. These are distinguished, microscopically, from the white portions of the groundmass only by a distinct medium-to-dark yellowish-brown staining, somewhat resembling that of limonite stain frequently observed discoloring tiny areas of the rock, derived from the partial leaching of any iron-bearing constituent in igneous rocks. No definite source of the staining was entirely indicated in any of the sections, but the areas clearly represent percolation of solutions of manganese and iron

salts through the rock. Why the definite arrangement into long pencils and dendritic forms manifested megascopically, evidence is again lacking, for the textural relations of the minerals in the discolored areas are precisely the same microscopically, as for other portions of the rock. The character of the staining suggests that the spotted and streaked appearance of the rock is a superficial phenomenon, and perhaps does not extend to any very great depth.

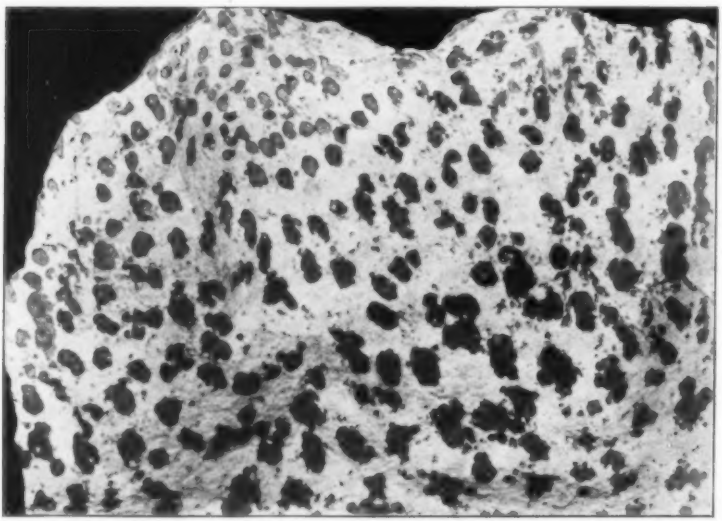

FIG. 4.—View showing weathered surface of the rock. Partial leaching of the dark spots is emphasized in the upper portion of the picture. Photographed from hand specimen. (One-half natural size.)

CHEMICAL COMPOSITION.

The chemical composition of the rock is given in analysis I of the table of analyses. The analysis of leopardite was made by Dr. F. A. Genth from the freshest fragments of the groundmass obtainable. The most striking features of the analysis are (1) the very acid character of the rock, as manifested in the high SiO_2 content; (2) the nearly complete absence of CaO and MgO; and (3) the increased Na_2O which is in excess of the K_2O. The analysis, however, har-

monizes closely with the microscopic study of thin sections of the rock, for the absence of ferromagnesian minerals accounts for the very slight amount of MgO present, while the practical absence of CaO and the large percentage of Na_2O prove the plagioclase to be albite, as indicated above by the microscope.

This analysis is compared in the table with a recent, more detailed one (II), of a quartz porphyry occurring in the northwestern part of the state, and with a spherulitic rhyolite (III) found east of the Charlotte locality in Montgomery county; and with analyses IV and V of well-known quartz porphyries occurring in other parts of the United States. A perusal of the figures given in the table will make clear the general similarity of the rocks, notwithstanding the rather striking differences indicated in some of the constituents.

TABLE OF ANALYSES.

	I	II	III	IV	V
SiO_2	75.92	79.75	79.57	73.12	72.85
Al_2O_3	14.47	10.47	11.41	14.27	13.78
Fe_2O_3	0.88	0.64	0.20	0.51	1.87
FeO	....	0.92	0.70	0.26	0.36
MgO	0.09	0.13	a little	0.24	0.42
CaO	0.02	0.15	0.21	1.10	0.87
Na_2O	4.98	1.36	3.46	3.43	4.14
K_2O	4.01	6.01	3.52	4.90	4.49
H_2O–110°C.	....	0.08	0.18	0.68	0.22
H_2O+110°C.	0.64	0.60	0.61	0.73	0.54
TiO_2	....	0.15	0.11	0.08	0.44
P_2O_5	....	trace	trace	0.03	0.13
ZrO_2	....	0.05	....	....	....
MnO	....	trace	....	0.06	0.06
SrO	....	trace	....	trace	....
BaO	....	0.06	0.05	trace	....
Li_2O	....	trace	....	trace	....
NiO	....	....	....	....	0.20
CO_2	....	....	....	0.77	....
Total	100.01	100.37	100.02	100.18	99.87

I. Quartz porphyry (leopardite), one and a half miles east of Charlotte, Mecklenburg county, North Carolina. *American Journal of Science*, Vol. XXXIII (1862, 2d ser.), p. 198. F. A. Genth, analyst.

II. Quartz porphyry—two and a half miles northwest of Blowing Rock, Watauga county, North Carolina. Petrographic data by Arthur Keith. Contains quartz and orthoclase, with subordinate sericite, chlorite, and biotite. W. F. Hillebrand, analyst. *Bulletin No. 168*, U. S. Geological Survey, p. 52.

III. Spherulitic rhyolite—Sam Christian gold mine, Montgomery county, North Carolina. Described by J. S. Diller, *American Journal of Science*, Vol. VII (1899, 4th ser.), p. 341. W. F. Hillebrand, analyst. *Bulletin No. 168*, U. S. Geological Survey, p. 53.

IV. Quartz porphyry.—Yogo Rock, sheet at head of Belt and Running Wolf Creeks, Little Belt Mountains, Montana. Described by Weed and Pirrson. *Twentieth Annual Report*, Part III, U. S. Geological Survey, pp. 520 ff. W. F. Hillebrand, analyst. *Bulletin No. 168*, U. S. Geological Survey, p. 125.

V. Quartz porphyry.—Six miles east of Ironton, Missouri. Described by E. Haworth, *Annual Report*, Missouri Geological Survey, Vol. VIII, 1894, p. 181. Melville, analyst.

WEATHERING.

In some exposures of the leopardite the weathered surface of the rock, which is still hard and firm, presents a lusterless, dead, chalk-like whiteness, the black spots of which are more or less bleached, changed from black to a reddish-brown in color. This alteration is brought out fairly well in Fig. 4, which is a photograph of a hand specimen of the partially weathered rock, reproduced one-half natural size. Bleaching of the spots is more emphasized along the top of the specimen, shown in the figure (4) in the contrasted lighter color of these spots to others in the same figure. When Fig. 4 is compared with those of the fresh rock, Figs. 1, 2, and 3, it is noticeable that all the spots in it have undergone some leaching, as indicated in their color being less intense or deep than for those in the fresh specimens of the rock.

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QUARTZ-FELDSPAR-PORPHYRY (GRANIPHYRO LIPAROSE-ALASKOSE) FROM LLANO, TEXAS.

THERE occurs in the vicinity of Llano, Tex., a porphyry which is very interesting petrographically, and may prove equally so commercially. It forms a large body whose shape and geological occurrence have not yet been described. It is said to be quite uniform in character. The material submitted by Dr. William B. Phillips, Director of the University of Texas Mineral Survey, for petrographical study is a gray porphyry with abundant phenocrysts of red feldspar and blue quartz, the matrix or groundmass being aphanitic to phanerocrystalline. It appears to have a crystalline texture, but the individual grains are not distinctly visible without a microscope. The rock is therefore mottled red and gray, with light blue spots of opalescent quartz.

The phenocrysts vary in size, the largest feldspars being 10^{mm} in diameter, the largest quartzes 5^{mm}. The quartzes exhibit a beautiful blue color, which is light sky-blue in the central part of the crystal and dark at the margin. The crystals are not all colored to the same degree; some are lighter than others. The color does not change perceptibly with a change in the angle of incidence, or in the position of observation, except that in certain positions there is a brilliant light blue luster. The feldspars are rather uniformly colored light Indian-red, the larger crystals being mottled with gray.

The proportion of phenocrysts and groundmass estimated from the surface of the specimen and from three thin sections is:

Phenocrysts	quartz	10.7
	feldspar	26.5
Groundmass		62.8
		100.00

Under the microscope the groundmass is seen to be holocrystalline and microcrystalline, and is composed of feldspar and quartz in nearly equal proportions, together with a small amount of brownish-green mica, and still less fluorite, magnetite, apatite, and zircon.

The proportions in which these occur was determined by microscopical measurement to be approximately, in 62.8 per cent. of groundmass:

		Total
Quartz,	23.9	34.6
Feldspar,	29.2	55.7
Biotite,	8.6	8.6
Fluorite,	1.0	1.0
Apatite,	0.13	0.13
	62.83	100.03

The fabric of the groundmass is uniformly heterogeneous, being a mixture of automorphic granular and micrographic. It consists of anhedrons of quartz, very free from inclusions, except some minute gas cavities, with similarly shaped anhedrons of microcline slightly clouded with alteration products, besides anhedrons of twinned albite with an approach to automorphism. These anhedrons vary in size from 0.1 to 0.01^{mm} in diameter. Throughout the whole are scattered at short intervals granular clusters of graphic intergrowth of quartz and feldspar. The crystallization of the graphic parts was almost contemporaneous with that of the anhedrons, as these are developed in continuous orientation with the graphic clusters.

The mica is xenomorphic in great part, and is in about the same sized anhedrons as the quartz and feldspar. It appears to have been almost contemporaneous in crystallization with these minerals. Its color is green to brownish-green.

Fluorite occurs in irregularly shaped anhedrons, xenomorphic in form. It is colorless in thin sections, exhibits distinct cleavage, and is characterized by its low refraction and isotropic behavior. It is quite uniformly scattered through the groundmass.

Apatite occurs in colorless microscopic prisms. Magnetite and zircon both occur in anhedrons in such small quantities that they were not measured. They appear to constitute a small fraction of 1 per cent. of the rock.

A careful study of the feldspars in the groundmass showed that microcline and albite are present in nearly equal proportions, and that they form separate and distinct crystals not perthitically intergrown.

The feldspar phenocrysts are microcline, with extremely minute and regular multiple twinning in two directions. The delicacy of the twinning suggests a possible soda content in the potash feldspar approaching soda microcline. There is also a perthitic inclusion of albite in irregularly shaped shreds, and also a slight clouding due to alteration, which is probably kaolin with hydrous oxide of iron which gives color to the feldspar.

The quartz phenocrysts contain multitudes of minute inclusions, rather evenly distributed through each crystal, except for a margin of nearly pure quartz in some cases. The inclusions are of two kinds, generally intermingled: one consists of extremely thin, colorless prisms, sometimes passing into lines of minute grains, like broken prisms; the other kind is in equally thin tabular crystals with six sides and trigonal shapes, and a light brown color. The colorless prisms have higher refraction than quartz, but the double refraction is not recognizable. They resemble apatite rather than rutile, having lower refraction than rutile and not being so long as rutile needles often are. The width of these prisms varies from 0.000800^{mm} to much less; that is, it is mostly a fraction of a wave-length of light. The brownish tabular crystals are equally thin, and range in diameter from 0.004^{mm} to much less. Studied by incident sunlight, they exhibit metallic reflections of a bluish-white and also of other colors. They have the crystal form and color of ilmenite.

These inclusions lie at all angles within the quartz crystals, but there appear to be sets of parallel directions intersecting at various angles, so that in some positions many tabular microlites reflect light in one direction. The same is true of the colorless needles. They lie in parallel lines crossing at various angles, whose orientation with respect to the inclosing quartz does not appear to be definite.

The sky-blue opalescent color of the quartz phenocrysts is undoubtedly due to reflection of blue light-waves from the minute colorless prisms, whose width is a fraction of the length of light-waves. It is similar to the blue color of the sky. It is probable, however, that there is also blue light produced by interference of the light reflected from both sides of the minute tabular crystals, whose thickness is also of the order of a fraction of a light wave-length; so that both kinds of phenomena occur within these quartzes.

From the microscopical measurements of the minerals and the optical characters of the feldspars it is possible to estimate approximately the chemical composition of the rock. The feldspars appear to be albite and orthoclase (potash microcline) in almost equal proportions in the groundmass, and the phenocrysts appear to have these molecules in nearly the same proportions. In assuming a chemical compositon for the brownish-green mica, the analysis of that in the soda granite (grano-liparose) of Cape Ann, Mass.,[1] was chosen.

On this basis the chemical composition of the rock was calculated to be that given in column I. This was done before chemical analyses of the rock were made, and the result is of great interest as showing how far this method of estimation may be relied on in favorable cases. If the microscopical measurements had been made to include the magnetite and zircon, the result would have been still more elaborate. Subsequently Analysis II was made by Mr. S. H. Worrell, of the University of Texas Mineral Survey, on a sample of the rock from the land of Mr. H. C. Harned, near Llano, Tex. As the alkalies were not separately determined in this analysis, Dr. H. S. Washington very generously undertook to analyze material from the specimen studied microscopically. The result is given in Analysis III. From

	I	II	III	IV
SiO_2	74.52	74.9	75.90	74.80
Al_2O_3	11.58	11.1	12.07	11.44
Fe_2O_3	0.69	1.6	1.01	1.07
FeO	2.61	1.5	1.45	1.62
MgO	none	.....	0.22	0.28
CaO	0.82	0.2	0.65	0.80
Na_2O	3.40	8.5	3.08	3.32
K_2O	5.46	tr.	5.32	5.52
H_2O+ / H_2O-	0.36	0.3	0.41 / 0.06	0.23
TiO_2	0.29	0.5	0.38	0.40
P_2O_5	0.05	.....	0.15	0.05
F	0.49	.....	n. d.	0.49
CO_2	.....	.....	none	.....
MnO	0.02	1.9	n. d.	0.18
	100.29	100.4	100.70	100.20
	less 0.21			less 0.21
	100.08			99.99

[1] See Table XIV in *Quantitative Classification of Igneous Rocks* (Chicago, 1903), mica analysis *e*.

these analyses it will be seen how close the microscopically estimated chemical composition is to that determined by chemical analysis.

The higher silica in III shows that the quartz in the rock was underestimated by 1.5 per cent., or that the piece analyzed by Dr. Washington was slightly richer in quartz phenocrysts.

The following data were determined in the laboratory of the Mineral Survey of the University of Texas: Specific gravity, 2.64; corrected, 2.67. One cubic foot of the rock absorbs 9.47 ounces of water. Crushing strength, 15,300 pounds per square inch of surface.

The alkalies in I and III are remarkably concordant, proving that the determination of the feldspars by optical means was correct; The lime determined in III corresponds to that estimated optically in fluorite and apatite. Fluorine appears only in Analysis I, and is very nearly correct, probably as much so as if determined by chemical means.

The correspondence between the two oxides of iron in both chemical analyses, II and III, the discrepancy in Anlaysis I, and the presence of a small amount of magnesia in III show that the mica analysis chosen from the Cape Ann rock is not the proper composition for the mica in the porphyry under investigation. The probable composition of this mica may be found by subtracting from Analysis III the chemical constituents of the known minerals—quartz, feldspar, fluorite, and apatite—and reckoning the remainder as mica and the extra quartz already mentioned. The result is as follows: extra quartz, 1.37 per cent.; mica, 8.6 per cent., having the composition (*a*).

	(*a*)	(*b*)		(*a*)	(*b*)
SiO_2	32.1	35.26	K_2O	6.8	9.20
Al_2O_3	19.2	10.24	H_2O	5.5	2.71
Fe_2O_3	11.7	12.47	TiO_2	4.4	4.68
FeO	16.8	18.84	MnO	.....	2.14
MgO	2.5	3.24		99.8	99.34
CaO	0.8	0.05			
Na_2O	.....	0.60			

This is approximately the composition of a lepidomelane like that in the nephelite-syenite (*grano-nordmarkose*) of Litchfield, Me.,[1]

[1] *Loc. cit.*, mica analysis *f*.

with a slight difference in the oxides of iron, and a notable amount of titanium oxide. It closely resembles the analysis (*b*) of lepidomelane from nephelite-syenite from the neighborhood of Langesundfjord, Norway, by Scheerer.[1] If this analysis of mica is used in the calculation of the chemical composition of the rock, the result is that given under IV.

The mica is clearly a lepidomelane rich in iron and alumina and poor in magnesia. When a greater variety of micas has been separated from igneous rocks and carefully described and analyzed, it will be possible to estimate the chemical composition of a rock from a microscopical investigation with greater accuracy.

The rock from near Llano, Tex., may be called a quartz-feldspar-porphyry having the composition of a granite. In the "Quantitative System of Classification" it is a graniphyro-liparose-alaskose.

The norm calculated from Dr. Washington's analysis, III, with the addition of fluorine determined microscopically from fluorite is given below under (1). The norm calculated from the mode by means of estimated Analysis IV is given under (2):

	(1) Norm	(2) Norm from Mode	Mode
Quartz	36.90	33.30	34.6
Orthoclase	31.14	32.80	27.8
Albite	26.20	27.77	27.9
Corundum	1.33	.....	....
Hypersthene	1.69	2.42	Biotite 8.6
Magnetite	1.39	1.62	tr.
Ilmenite	0.76	0.76	tr.
Apatite	0.34	tr.	0.13
Fluorite	0.70	1.00	1.00
	100.45	99.67	100.03

The rock is a persalane with about 5 per cent. of femic components. Following the norm from Dr. Washington's analysis, the quartz is so abundant that it is quarfelic, columbare, near the quardofelic order britannare. It is therefore a britannare-columbare. It is peralkalic of the most extreme kind, having no anorthite feldspar, the lime being entirely femic, in fluorite and apatite. It is alaskase near liparase, a liparase-alaskase. And with respect to

[1] See W. C. BRÖGGER, *Zeitschr. Kryst. Min.*, Vol. XVI (1890), p. 191.

alkalies it is sodipotassic, and hence an alaskose near liparose: *liparose-alaskose*. If the norm derived from the mode were made a basis of classification, the rock would be quardofelic, a britannare, near columbare. From this it is evident that the rock is intermediate between these orders, and may be a liparose-alaskose, or an alaskose-liparose.

JOSEPH P. IDDINGS.

CRYSTOSPHENES OR BURIED SHEETS OF ICE IN THE TUNDRA OF NORTHERN AMERICA.

SHEETS or layers of clear ice have often been recorded as occurring in the alluvial deposits or in the sphagnum swamps of Arctic or sub-Arctic America, and most of the travelers who have made even short visits to the far north have noticed the occurrence of these ice-sheets in small escarpments on the edge of the tundra. I myself observed them in a number of places along the southern edge of the Barren Lands, in the country between the Mackenzie River and Hudson Bay, and drew attention to the fact that some of them, at least, were moving slowly down the gentle slopes on which they were lying. Since coming to the Yukon Territory I have had many opportunities of seeing and examining them in the frozen bogs which cover the bottoms of most of our valleys.

As the mode of formation and growth of these ice-sheets for a long time appeared to be rather difficult to explain, the following remarks with regard to them may be of interest.

The Klondyke gold-bearing district, to which my observations have lately been confined, and in which the deductions here set down were drawn, is a part of a great unglaciated belt or tract of country lying near the middle of the Yukon Territory in Canada, between the glaciated region which extends on both sides of the "Chilcat" or Coast Range of mountains to the south and southwest, and the also glaciated region of the Ogilvie or Rocky Mountain range to the north and northeast. It is a country of high, well-rounded hills and deep, though flaring, valleys, in the bottoms of which flow streams with regularly decreasing grades. On one or both sides of these streams are everywhere deposits of alluvial material, varying from ten to a hundred feet in depth, consisting below of coarse sand and gravel, above which are fine sands with peaty and vegetable material, the uppermost layer, locally known as "muck," usually consisting almost exclusively of sphagnum swamp. The streams flow on beds of the coarser alluvial gravel or sand, seldom touching the underlying rocky floor, and are at present confined in relatively

shallow channels, the sides of which consist of the peaty and finer alluvial material. Ponds or lakes are conspicuously absent.

The surface of the whole country, whether composed of "muck," gravel, or rock in place, is almost everywhere permanently frozen, and while as yet comparatively few shafts have been sunk through this frozen layer, the evidence at hand would seem to show that it

FIG. 1.—Ice formed by spring water in winter.

has a thickness varying from forty or fifty feet on the higher, uncovered parts of the hills, to two hundred feet in the moss-covered bottoms of the valleys. Here and there, however, there are unfrozen channels in the otherwise frozen layer, through which springs issue from the sides of the hills, carrying water from the deeper saturated, and unfrozen ground through the frozen layer to the surface.

Most of the known springs issue from the rock above the surface of the alluvial deposits in the bottoms of the valleys, but some have been exposed by mine workings beneath the ordinary surface levels. They all discharge more or less water throughout the year,

their flow being but slightly, if at all, affected by the conditions of the weather, or even by the most extreme seasonal changes of temperature. In summer those that issue from the rock above the alluvial deposits discharge over the surface into the nearest brooks or rivers, and, except where used as local supplies of clear cold water for household purposes, are rarely noticed; but in winter, when the thermometer occasionally falls as low as —60° F., the water flowing out into the cold air freezes within a comparatively short distance, and by the close of the winter it may have formed a mass of ice many feet in thickness. These ice-masses are locally known as "glaciers," and where they form along the lines of roads are often serious obstructions to travel.

But, in addition to these masses of ice formed on the surface every winter, and which regularly melt away during the following summer, other masses are formed beneath the surface in such positions that they are protected from the action of the sun and atmospheric agencies; and thus it is possible for them to increase from year to year to very considerable dimensions. These underground masses of clear ice are also locally known in the Klondyke country as "glaciers," but the name "crystosphene" (*κρύσταλλος* "ice"; *σφήν*, wedge") is here suggested for them, as indicating a mass or sheet of ice developed by a wedging growth between beds of other material, while the name "crystocrene" (*κρήνις*, fountain), is suggested for the surface masses of ice formed each winter by the overflow of springs.

Crystosphenes are formed by springs which issue from the rock under the alluvial deposits that cover the bottoms of the valleys. As a rule, they occur as more or less horizontal sheets of clear ice, from six inches to three feet or more in thickness, lying between layers of "muck" or fine alluvium, usually where the "muck" is divided horizontally by a thin bed of silt or sand; and most of them, as far as my observation goes, are from two to four feet below the surface, though some are deeper. In area they differ greatly. One observed by the writer on the shore of Daly Lake, near the southern edge of the Barren Lands west of Hudson Bay, seemed as if it might underlie a square mile or more, while many of those in the bottom lands of the gold-bearing creeks of the Klondyke district vary in length from a hundred to a thousand feet, and in width from fifty

to one or two hundred feet, as shown by shafts sunk through them at various places.

Speaking generally, these ice-sheets are of very even and regular thickness throughout, though they are not strictly horizontal, but approximate closely to the slope of the surface under which they lie. For instance, the city of Dawson is built on an alluvial bottom land declining gently from the base of a steep hill to the banks of the Yukon and Klondyke Rivers, and a crystosphene which here underlies the surface at a few feet beneath it seems to have about the same slope. In another case a crystosphene was encountered on a mining claim on Hunker Creek three feet below the surface, and it was traced for five or six hundred feet down the valley, being everywhere at practically the same depth, while the surface itself had a slope of about one in a hundred, so that this apparently level sheet of clear ice was five or six feet higher at its upper end than at its lower. Examples of this kind could be multiplied almost indefinitely, showing plainly that these ice-sheets do not partake of the character and attitude of frozen ponds or lakes.

While these crystosphenes, or so-called "glaciers," are usually of the nature of nearly horizontal sheets, occasionally they occur as veins or dikes of ice rising through the bed-rock into the overlying gravel. Two such veins of ice were very well exposed in the underground workings on mining claim No. 39, below Discovery on Hunter Creek, where they evidently represented the former course of a spring, which had changed its point of discharge. More or less vertical masses of ice are also sometimes met with in the gravels themselves, indicating the positions of former water channels from the bed-rock toward the surface.

In the majority of cases crystosphenes are in the vicinity of springs that can be plainly seen issuing from the bases of the neighboring hills, but in other cases no such springs are apparent. In these latter cases, however, wherever the gravel has been removed, and the underlying rock has been exposed, springs have been found. While studying the origin of the crystosphene 600 feet long, already mentioned as occurring on Hunker Creek, no springs were apparent in the immediate vicinity, and at first it seemed as if the ice must have been formed from water flowing from a spring three or four hundred yards farther up the valley; but finally a little trickling

stream was found issuing from the rock several feet below the level of the top of the alluvial deposits. This was the source of the water that had formed the ice.

The mode of formation of these underground sheets of ice is therefore somewhat as follows:

Water, issuing from the rock beneath a layer of alluvial material, rises through the alluvium, and in summer spreads out on the surface, tending to keep it constantly wet over a considerable area. In winter, if the flow of water is large, and the surface consists of incoherent gravel, the water will still rise to the surface, and there form a mound of ice. If, on the contrary, the flow from the spring is not large, and the ground is covered with a coherent mass of vegetable material, such as is formed by a sphagnum bog, the spring water, already at a temperature of 32° F., rises till it comes within the influence of the low temperature of the atmosphere above, and freezes. This process goes on, the ice continuing to form downward as the cold of the winter increases, until, a few feet below the surface, but still within the influence of the low external temperature, a plane of weakness is reached in the stratified and frozen vegetable or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand.

As any outlet to the top is now permanently blocked, the water is forced along this plane of weakness, and there freezes; and thus the horizontal extension of the sheet of ice is begun. While thus increasing in extent, the ice also increases in thickness by additions from beneath, until it has attained a sufficient thickness so that its bottom plane is beyond the reach of the low atmospheric temperature above; after which it continues to increase in extent, but not in thickness or depth.

With the advent of the warm weather of summer the growth of the crystosphene ceases, but the cold spring water which continues to rise up beneath it has very little power to melt it, and its covering of moss or muck, being an excellent non-conductor of heat, protects it from the sun and wind, and prevents it from thawing and disappearing. Thus at the advent of another winter it is ready for still greater growth.

J. B. TYRRELL.

DAWSON, YUKON TERRITORY, CANADA,
February 13, 1904.

A COAL-MEASURE FOREST NEAR SOCORRO, NEW MEXICO.

We have grown so accustomed to consider that in the Rocky Mountain region the period represented in the eastern states by the deposition of coal was inimical to terrestrial life, or otherwise so different from the corresponding eastern time in its conditions that it is useless to search for a coal flora, that considerable interest attaches to any area, however restricted, in which a genuine Coal-Measure flora is present.

Such an area became known to the writer a number of years ago, but it long proved impossible to study the locality in person. A small suite of fossils reported to have been collected in the fire-clay beds east of Socorro was placed in the writer's hands by Mr. George Thwaites, and, after several fruitless attempts to identify the locality, the occurrence was reported, and, later, figures were given of four species of lepidodendrids which could be distinguished as distinct. There figures occur on Plate VII of the *Bulletin of the University of New Mexico* for 1900. No descriptions were given, and considerable uncertainty still existed as to the age of the formation from which they were derived.

More recently the writer has not only been able to locate the place and add to the original collection of specimens, but he has carried out a considerable amount of field work in the immediate locality which will suffice to settle the principal questions of stratigraphy so long left open.

Whenever the nature of the contact between the granite and the superjacent rocks shall be studied carefully throughout the territory, many interesting points will be brought out. Whether the granite itself is a homogeneous element or represents various periods must be left an open question. We have every reason to conclude that it represents the metamorphosed sediments of an early geological time, and the writer has already reported instances where limestone beds within the granite have been found to contain what greatly resemble altered organic remains. It is also known that the gran-

ites, in common with the immediately overlying strata, have suffered great erosion in the early part of the so-called Permian. This period of elevation, disturbance, and oscillation does not, however, seem to mark any great lost interval, so far as the record shows, while the interval represented by the granite contact is undoubtedly a considerable and variable one. The disturbance which lifted the granites above the reach of the sea may not have been very extreme, and it is not likely that the present extreme of metamorphism was reached till long after, though it was certainly before the time in which the breccias and sandy beds of the Permian were formed, for these strata contain granite fragments in abundance.

At any rate, when the sea began to return by subsidence of the granite, this encroachment was gradual, and from the south toward the north and northwest. This is proved by the fact that the exposures in the southeastern counties reveal vast deposits between the granite and the Carboniferous in which we have identified strata as old as the Burlington, superposed upon others yet older, but not identified as yet. In the southwestern part of New Mexico there are still earlier strata, some of which have been referred to the Devonian (*Hamilton*). The writer hopes to enter upon this subject more in detail in another place; at present it will be sufficient to indicate that as far north as in Socorro county the stratified rocks overlying the granite have revealed no remains indicating an age earlier than the Carboniferous, and the writer knows of no positive datum representing anything older than the Coal Measures. It is true that there are reports of Subcarboniferous crinoids from the Graphic-Kelly beds lying upon the crystallines near Magdalena, but inasmuch as this 100 feet or more of crystalline limestone, which is so interestingly developed in the lead district, is not found in the locality under discussion east of the Rio Grande, nor yet farther north in the Rio Grande valley, it may be said roughly that the boundary between the lower formations and the Coal Measures passes through Socorro county.

Corresponding to the change just described is a still more pronounced geographical change in the character of the Permian and "red bed" deposits, which have an entirely different facies and succession in the northwestern counties from the typical Texas sequence exhibited in the southeast.

The writer has described the Rio Grande valley as a region of early uplift—in effect an anticline, though the anticlinal axis is not exposed to view—and accordingly the dip of the strata is prevailingly to the west on the west side and to the east on the eastern side of the valley. The granite core of this anticline is largely removed, but is exposed in the bases of the Sandia, Manzana, San Andres, and Organ mountain ranges on the east side of the valley, as well as in the core of the great Sierra Ladrone uplift and the base of the Limitar Mountain on the west.

The interval between these remaining buttresses of the great eroded mass is now, for the most part, filled with late strata composed of Tertiary (Santa Fé marls) and Pleistocene deposits, mostly nearly horizontal, except in proximity to the areas of late volcanic disturbance. There are also perforating necks and cones of basalt, as well as interstrata flows and dikes of the same material, but of an older period.

In the *American Geologist* of recent date[1] the writer announced the discovery of granite masses in the valley in the midst of the Tertiary beds, and gave a section extending from the Rio Grande east of Socorro through these granitic bosses. This section is so taken as to pass through the region here under discussion, though it does not cut the exact locality in which the fossil coal flora was found.

These granite ribs (Fig. 1) are two in number, and are separated by an interval of perhaps half a mile, which is partly covered by the Tertiary beds, but, wherever cut by arroyos or canyons, the lower or Sandia formation of the Coal Measures is exposed in basin-like relation upon the granite, forming a shallow syncline (really a modified monocline). The western rib or elongated boss of granite rises not over 100 feet above the canyon level, and presents a sharp slickensided fault to the west, with a course some twelve degrees east of north where measured. In some places the Tertiary wholly covers the boss, and to the north and south the granite passes out of sight beneath this formation, the entire length being perhaps two miles, as exposed. The eastern exposure presents the overlying but unconformable Coal-Measure formation consisting of shales, silicious shale, quartzite, and ferruginous conglomerate near the contact,

[1] "Laws of Formation of New Mexico Mountain Ranges," May, 1904.

followed by a large series (over 200 feet) of alternating shales, quartzites, and earthy or sandy limestones, the latter being quite fossiliferous.

Of the Graphic-Kelly formation which in the Magdalena Mountains, a few miles to the west, separates the Sandia series from the granite, there is no trace.

The Coal-Measure rocks soon become horizontal, and at the eastern side of the basin, where they abut upon the eastern boss or rib of granite, they dip to the west and lie in juxtaposition to a fault exactly similar to that on the western side of the first-mentioned or western rib. In fact, the eastern rib is to all intents a repetition of the first,

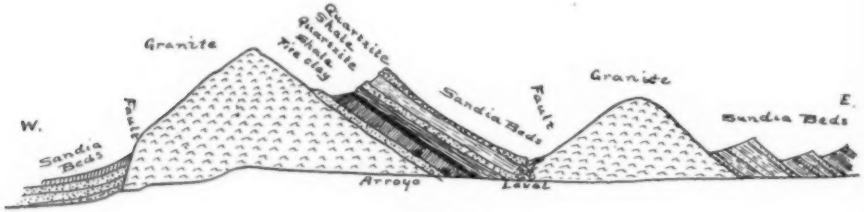


FIG. 1.

and the Sandia series is repeated on the eastern aspect in all essential respects as it occurs to the east of the western granite rib.

Locally, however, there is a third fault which serves to repeat the granite. This fault is a few hundred yards east of fault No. 2, and in the interval there are preserved a few of the Sandia strata, though in many places they are entirely removed by erosion. It is in the V formed by these two faults that the best example occurs of the fire-clay beds with the inclosed plant remains. In other localities the fire clay also occurs beyond the influence of this local fault, but these points are as yet little explored, and, in several localities visited, the granite contact has only a silicious shale in the place of the fire clay.

The dip of the strata as they repose on the granite may be as high as 70 degrees, but more often about 45 degrees. Passing eastward, one crosses in succession a number of low hills, each capped by a bed of quartzite, the intervals being filled with shale and limestone, the superior resistance of the quartzites having thus impressed itself upon

the topography. When the top of the Sandia formation is reached, the topography changes, and the country rises in abrupt escarpments of massive to earthy limestone of the characteristic Upper Coal-Measure habitus. At the base, this formation is locally very fossiliferous with the well-known Coal-Measure assemblage, a partial list of which will be given below.

The first escarpment may rise some 100 to 150 feet, and is followed by others of the same character, indicating a probable aggregate thickness of 300 to 500 feet. The continuity of the section is here broken by what may be called the "Cane Spring monocline" or fault zone. This will be more particularly described later on, and it will here be noted that this break forms in effect a rough delimitation of the Carboniferous from the so-called Permian. To the east of this the hills are mostly composed of earthy limestones, with shales of prevailingly reddish color, with gypsum beds and calcium anhydrite deposits to the base of the great escarpment forming the sky-line to the spectator from the west side of the river at Socorro. This ridge, which is the southern continuation of the Cibolo (Seboyo) Mountains, consists of from 500 to 600 feet of red beds, with gypsum and anhydrite inclusions, capped by 150 to 175 feet of yellowish sandstone and 100 to 200 feet of gray, massive, non-fossiliferous limestone, with at least one small band of quartzite. Still to the eastward are hills containing the typical upper red-bed formations. To the south this whole series disappears beneath the Carthage coal fields of Cretaceous age.

To return to the plant beds, it will be noted that the fire clay, with its attendant shales, reposes directly upon the granite, or with a thin layer of quartzite between. The clay is of good quality, but very irregular, and has formed the base of the fire brick manufactured by the Socorro Fire Clay Co. In the clay, and especially in the shales overlying, are the remains of lepidodendrids and other coal plants referred to. A thin seam of coal is apparently present, though at the time of our inspection there was no opportunity to discover it in place. Report affirms that a boring one and one-half miles south encountered two small coal seams within 200 feet.

The thickness of the clay and attendant shales is not over 30 feet, of which half may be roughly estimated as clay. Then follows 10

feet of silicious shale capped with quartzite, and 15 feet of similar shales also capped with about 5 feet of quartzite. This is all that remains of the great Sandia beds at this place, but to the east, on the other side of the third granite mass, the series is complete. This occurrence may be termed the "Incarnacion" fire clay, and the same name will apply to the granite exposure, it being the name of the mining district in which these exposures occur.

There would seem to be no reason for separating the fire clay from the Sandia formation, it being but a local variation, and, even where the clay is not found, obscure plant remains attest the similarity of conditions to some extent.[1]

The Cane Spring fault area.—In this connection it may be desirable to call attention to this profound dislocation, the exact nature of which varies from point to point, but which is apparently found at a distance of a mile or more to the west of the main escarpment of the Cibola ridge. It lies nearly midway between the Incarnacion granite ribs, with their faults, and the main range just mentioned. The typical exposure is, however, at "Ojo de las cañas," or Cane Spring, a permanent water in the large arroyo joining the Rio Grande immediately south of Socorro and owing its existence to the faulted area. A section extending from the fault to the Cibola ridge is given, the data being approximate, but sufficient to give some idea of the conditions.

The disturbance is profound and has the appearance of being a double anticline with an interval separating the two members of some eighth of a mile. At Cane Spring, where the disturbance is most easily seen, about 700 feet of red, green, and yellow sandstone, shale, and marl are tilted up at a high angle, with the appearance of an appressed fold, the dip being to the west on the west side and to the east on the opposite side of the axis. The western limb is concealed by a covering of Tertiary, but on the east is a sharp fault, against which the nearly horizontal strata abut with little inclination. Thence eastward there are exposed by the arroyo about 100 feet of red and yellow sand and marl to the second break, which is very similar to the

[1] Since writing the above, similar plant remains (*Lepidodendron* sp., same as Fig. 9 below) have been found in the lower part of the Sandia series on the west side of the Ladrones Mountains, where the Sandia quartzite reposes directly upon the metamorphic rocks (schists and granites).

one just described. The section figured (Fig. 2) is a mile or more north of the spring, but has a similar double character. It is impossible to be certain that the disturbance is due to a double appressed fold separated by faults, but such is the appearance. At this locality the western side of the break is also exposed, and is a distinct fault, with much alteration and excretion of quartz. A curious quartz breccia is a feature of the fault on the western side. The upper Coal Measures or Permo-Carboniferous appears on the west, and about half a mile west of the fault we found fossils including *Phillipsia major* and other types known to be well up in the series.

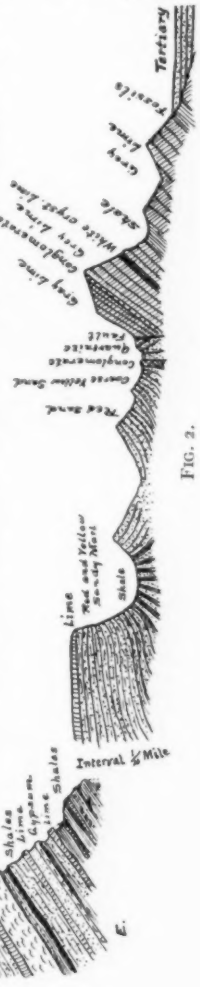


FIG. 2.

Unfortunately, the paleontology of the Sandia series is too little known at present to enable us to locate it definitely with respect to the divisions now recognized in the Middle West. We have determined in it, immediately above the fire clay beds, *Productus costatus*, *Spirifer cameratus*, *Ambocoelia planoconvexa*, *Seminula argentea* (small form), *Derbia crassa* (?), bryozoa, etc. In the lower part of the division immediately following the Sandia beds there is a large fauna, of which the following may be mentioned: *Eupachycrinus verrucosus*, *Reticularia lineatus*, *Ambocoelia planoconvexus*, *Spirifer striatus*, *Spirifer cameratus*, *Productus cora*, *Productus nebracensis*, *P. semireticulatus*, *Seminula argentea* (large form), *Derbia crassa*, *Chonetes granulifera*, *Dielasma bovidens* (rare at this horizon, abundant higher up), *Streblopteria* (?). It may be noted that *Eupachycrinus* is known in the Kansas section from the Earlton to the Severly, *Chonetes granulifera* commences in the

Leucompton beds and extends upward, *Streblopteria* begins in the Earlton. So far as can be determined at this writing, the position is near the horizon indicated by Iola limestone, or within the Pottawatomie formation of Haworth. This is above the base of the Upper Coal Measures.

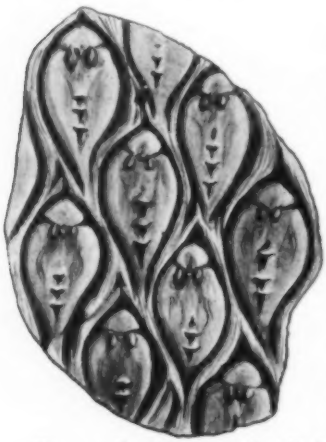


FIG. 3.—*Lepidodendron thwaitesi*, sp. n. (One-half natural size.)

Below are given in tabulated form, for comparison, some of the more complete sections across the Permo-Carboniferous. It will be found that there is always a well-marked change in lithological character of the rock at the horizon of the Manzano quartzite. Here is evidence of an unconformity by overlap. The lime breccias or small strata of lime with angular fragments of earlier lime and granite are quite characteristic of this general belt, and the Manzano beds themselves usually contain vast quantities of red granitic débris. Often vein quartz is present, and it is also common to find impressions of tree trunks. All of these phenomena indicate proximity of land and a period of disturbance. The Sandia formation is easily distinguished, but it is more difficult to decide upon divisions of the Upper Coal Measures above that section. In general, there is a change of fauna, though numerous species pass unchanged throughout. *Productus punctatus*, *Dielasma bovidens*, and *Meekelia* are characteristic of the upper portions. The large *Fusulina* is found at a higher level than the common *F. cylindrica*.

FIG. 4.—*Lepidodendron thwaitesi*, sp. n. (Single bolster, enlarged.)

SECTION EAST OF SOCORRO.

Gray lime	25–50 ft.
Red quartzite	10
Gray lime	65
Whitish to yellow sandstone	150
Red marly beds with lime, etc.	100–150
Earthy lime	10
Anhydrite	50–75 ft.
Sandy shales, shales, and lime	100
Gypsum	5
Sandy shales, marls, and lime	Indef.
Red beds, as above	Indef.
Lime (hard greenish, earthy)	10
Yellow sandstone	20
Red sandstone	30
Silicious shales	
Alternating shales (quartzites, green limestone, red flags)	300–500
Red granitic conglomerate quartzite.	
Massive limestone (fossiliferous)	25
Manzano (massive) quartzite	40–50
Lime breccia.	

Top of Upper Carboniferous formation (*c* 130).

Massive limestones, shales	60–75 ft.
Calcareous conglomerate	5
Limestone	50
Sandy conglomerate (*b*, 147)	5
Limestone	5
Silicious shale	2
Earthy limestone	35
Massive and shaly lime	100
Yellow sandstone (*a*, 66 ft.)	15–20
Shaly lime	6
Massive lime	3
Shaly lime	8
Massive lime	4 ft.
Shaly lime	6
Massive lime	4
Shales and shaly lime	15

Top Sandia formation (235 ft.).

Red quartzite	4
Red shale	10
Quartzite	6
Shale	10
Sandy lime (fossiliferous)	6
Quartzite	8
Shale	10
Limestone (fossilferous)	3
Shale	6
Limestone	4
Shale	6
Quartzite	4
Shale	
Limestone	4
Shale	6
Red coarse sandstone	20
Green fissile shale	25
Earthy limestone	5
Sandy shales and quartzite	50
Coarse quartzite	8
Clay and shale (Lepidodendrids)	35
Contact quartzite	Indef.
Granite.	

SECTION NEAR COYOTE SPRINGS, SOUTHEAST OF ALBUQUERQUE.

(Permian not exposed; see below.)

Massive limestone	10 ft.
Nodular limestone	3
Massive limestone	4
Shaly limestone	28
Granular limestone	3
Micaceous shales.	
Coyote yellow sandstone (*b*)	2–30
Massive limestone	85
Fusulina limestone	23
Shale (bryozoa)	2

Massive limestone	48 ft.	Sandy lime	17 ft.
Shaly limestone	47	Massive limestone and Sandy shaly lime	28
Massive limestone	15	Fusulina cylindrica beds	
Shales (Flint Ridge beds)	33	Shales	28
Green quartzite	2	*Top of Sandia formation* (119 ft.).	
Massive limestone (productus)	12	Sandy shale, with bands of limestone, alternating with quartzite	45
Nodular shaly lime	2	Silicious fossil lime	2
Massive limestone	30	Sand and shales	22
Black shaly lime	48	Basal quartzite	50
Massive lime	3	Granite or gneiss.	
Lime and lime shales	40		
Sandstone (*a*)	2- 4		

Near the locality in which the Coyote section was measured a section was taken which is more complete toward the top and serves to supplement the above section. That part of it above the Coyote sandstone horizon is here given:

Manzano quartzite, red and yellow granitic sand, and conglomerate with silicified wood and granitic pebbles	55 ft.
Top of Upper Carboniferous.	
Earthy lime with lime breccia, etc.	50
Earthy lime with green bands (bryozoa)	25
Earthy cherty lime (*Productus punctatus*)	16
Massive lime (*Productus cora*)	25
Black shaly lime (*Dielasma bovidens*)	17
Bryozoa beds.	
Gray lime (*Fusulina robusta?*)	6
Massive lime	22
Coyote sandstone horizon.	

Below this point the section corresponds essentially with the section given above. This corresponds to a total thickness of the Coal Measures of 750 feet, of which about 130 feet is formed by the Sandia beds. The section east of Socorro contains about 600 feet, of which 235 feet is contributed by the Sandia beds.

In order to indicate the amount of variation in the same region, a section is here given corresponding with that last above recorded and taken only a short distance east of it in the Coyote district:

Massive earthy lime with *Bellerophon, Productus punctatus*, etc.	72 ft.
Allorisma and numerous fossils.	
Sandstone	40

Earthy fossiliferous lime	17 ft.
Sandy shale and granular lime	5
Earthy limestone (*Dielasma bovidens, Discina*, etc.)	11
Calcareous sandstone	14
Green sandy shale	6
Reddish yellow sandstone (Coyote)	40
Massive earthy lime.	

It appears that this last section falls a little short of reaching the Manzano quartzite and develops a great deal more of the sandy

FIG. 5.—*Lepidodendron thwaitesi*, var. *striolatum*, var. n. (One-half natural size.)

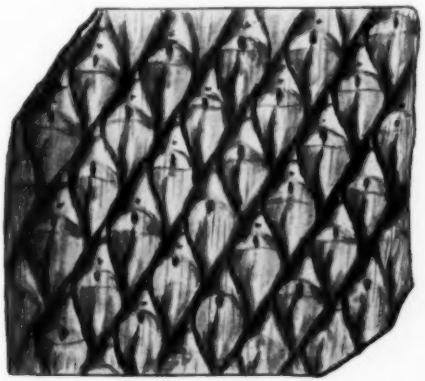


FIG. 6.—*Lepidodendron socorroense*, sp. n. (One-half natural size.)

materials that are found farther west, though the Coyote sandstone has been observed to be 40 feet thick in one place, and entirely absent or reduced to a few inches within the distance of half a mile in continuous exposure.

For comparison, the following incomplete section may be given from the escarpment west of the Rio Grande in about Township 5 N., Range 4 W., of New Mexico P. M. This locality is northwest of the Ladrones Mountains.

Lava flow (basalt).	
Red flags and shales (position uncertain)	200-300 ft.
Fault.	
Limestone with (Permian?) fossils	15

Limestone and shale	90 ft.
Sandstone shale with lime bands	10
Gray limestone	100
White sandstone	40
Gray (gypsiferous) shales	20
Yellowish sandstone	100
Yellowish shale	5
Reddish gypsiferous shale	175
Anhydrite and limestone resting on fissile shale	100
Gray shales	Unexposed.

Red flags and shales (several hundred feet).

Carboniferous limestone (Coal Measures). At least 400 ft.

The Carboniferous is separated from the detailed section by a valley perhaps a mile wide filled with low hills of the red beds, the dip being in all cases to the east. It is therefore very difficult to determine the thickness of the red beds, nor is it certain that there is no dislocation. There is the same difficulty in determining the extent of the fault at the top of the detailed section, but it is presumed that the throw is small, though there is an area of vertical strata intervening.

FIG. 7.—*Lepidodendron socorroense.* (Enlarged bolster of different form.)

It is not difficult to conclude that the detailed section here given corresponds in a general way with that east of Socorro above the sandy shales, etc., marked as "indefinite." In fact, it would appear that the thick anhydrite bed is a very convenient and rather constant bench mark, however variable it may be in thickness.

References may here be made to the section given in the writer's article on the "White Sands."[1] This section is from a locality comparatively rich in fossils of a decidedly Permian habitus.

PLANTS OF THE INCARNACION CLAYS.

The following descriptions are given as a matter of convenience, in spite of the fact that it has not been possible to compare our specimens with eastern types. The forms seem to be new, and may serve to assist in calling attention to similar occurrences in the Southwest.

[1] *Bulletin of the University of New Mexico,* Vol. II, Fasc. 3, p. 10.

FIG. 8.

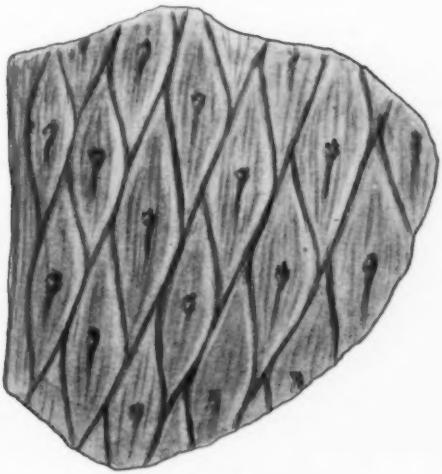


FIG. 9.

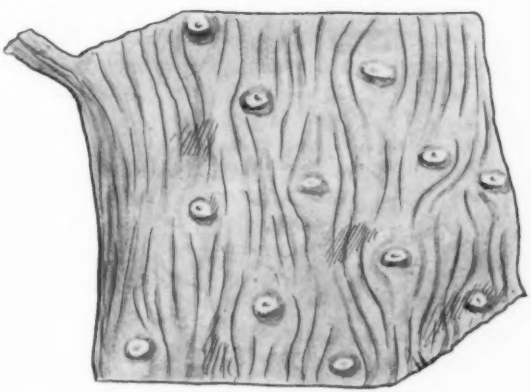


FIG. 10.

FIG. 8.—*Lepidodendron keyesi*, sp. n. (One-half natural size.)

FIG. 9.—*Lepidodendron* sp. ? (One-half natural size.)

FIG. 10.—"*Stigmaria*." Root of one of the above?

Lepidodendron thwaitesi, sp. n. (Figs. 3 and 4.)

(*Cf. Bulletin of the University of New Mexico*, Vol. II, Plate VII, Figs. 2 and (?) 4.)

Trunks of large size. Bolster somewhat oval, kite-shaped to rhomboidal, about two and one-half times as long as wide, rather thickly set, but separated by high striated ridges; length of bolster, 0.9 in.; width, 0.4 in.; 1.2 in., and 0.45 in., 1.3 in. and 0.5 in., in three cases; seven bolsters in the space of 4.5 in., measured obliquely along the rows in branch over 6 in. in diameter, seven in 5 in. in a larger specimen. Leaf scars (cicatrix) small, transversely oval, about one-fourth as long as entire bolster. Middle of bolster below the cicatrix marked with a ridge or depressed cauda, crossed by three very distinct frets. Transpiring vents well marked on either side below the cicatrix, with which they are connected; vascular trace punctiform, often absent. Ligular scar near apex of cicatrix, triangular, often apparently notching apex of cicatrix. An escutcheon-like impression between transpiratory vents. Leaves sharply acuminate with slender tips, midrib strong, 3 in. wide and perhaps 8 in. long.

Lepidodendron thwaitesi, var. *striolatum*, var. n. (Fig. 5.)

Greatly resembling L. thwaitesi, and perhaps a variety of that species, but represented by smaller specimens in which the preservation is not very perfect.

Bolsters uniformly rhomboidal oval, surface flat, about five in the space of 2.4 in. measured diagonally in the rows. Length, 0.72 in., width, 0.35 in. Space below the cicatrix marked with numerous (5–7) irregular frets. Cicatrix apparently as in *L. thwaitesi*.

Lepidodendron socorroense, sp. n. (Figs. 6 and 7.)

(*Bulletin of the University of New Mexico*, Vol. II, Plate VII, Fig. 1 ?)

Trunks of moderate size, leaves slender. Bolsters rhomboidal to rhombic oval, acuminate at the ends, nearly symmetrical; lower portion, from the leaf scar downward, kite-shaped to rhomboidal, upper margin curved, the long axis marked by a well-defined keel, very prominent near the lower angle, where is an elevation; folar cicatrix about one-fourth the entire length of bolster; transpiratory appendages obscure; vascular pore on the most prominent part of cicatrix; a deep pit below the cicatrix on median line; ligule large, well marked. Bolsters closely approximate, in well-defined oblique series; 0.7 in. long, 0.3 in. wide. In a trunk 3.2 in. in diameter 9 bolsters in space of 3.5 in., measured diagonally in the rows; in larger trunks 9 bolsters in 4.3 in.

This species is well represented, and is variable in size, but the specimens leave much to be desired in detailed structure of the leaf scars.

Lepidodendron keyesi, sp. n. (Fig. 8.)

Trunk of large size. Bolsters large, obovate, flat, closely approximate, in well-defined diagonal rows. Eight bolsters in space of 4 in., measured obliquely

in the rows. Length of bolster, 0.75–0.8 in.; width, 0.5 in. Cicatrix nearly reaching middle of length of bolster: ligule very large, often causing the upper part of cicatrix to appear emarginate. Transpiratory appendages large, oval, discrete. A groove extends from cicatrix to the lower angle of the bolster, and there are traces of frets. State of preservation imperfect. Named in honor of Dr. Charles R. Keyes, of the New Mexico School of Mines.

Lepidodendron, sp. ?. (Fig. 9.)

(*Bulletin of the University of New Mexico*, Vol. II, Plate VII, Fig. 3.)

In form of bolsters this form is like *L. brittsi* or *L. aculeatum*.

All our specimens seem to be decorticated, so that it seems unsafe to attempt a description. It is even possible that these specimens belong to one of the above species, although in appearance they differ widely.

There are five bolsters in a space of 3.7 in., measured diagonally in the rows. Length of bolster, 1.6 in.; width, 0.4 in. Vascular scar above the middle. Surface of (decorticated) specimen striolate.

C. L. HERRICK.

SOCORRO. N. M.

THE VARIATIONS OF GLACIERS. IX.[1]

THE International Committee on Glaciers met in Vienna last summer, and the retiring president, Professor S. Finsterwalder, presented a report to the International Congress of Geologists, of which the following is a brief summary:[2]

Although the committee has been at work only nine years, a time too short for very general results, still we can say that the thirty-five years' period which Brückner found in the variations of the Alpine glaciers applies also to glaciers in other parts of the world. It is also probable that there are longer climatic periods than this whose course is very complicated; moreover, the individual character of the variations of special glaciers is, without doubt, dependent upon the topography of their basins. We therefore have to do with variations of a very complicated character, as they depend both upon climatic changes and upon individual characteristics. But we can say, in general, that the dominating tendency of glaciers at the present time is to retreat. There are many exceptions to this rule, the reasons for which are not understood. The Mont Blanc group showed some tendency to advance in the eighties, and within the last twenty years this advance has been transferred to the most easterly Alps, though not advancing regularly over the intervening regions.

The Vernagtferner presents the most remarkable phenomena. This glacier increased 400^{m} in length between 1897 and 1902, which is not so extraordinary for it; but, in addition, the velocity of flow in a certain profile near the end increased from 17^{m} to over 250^{m} per year, and then suddenly within one year sank back to 80^{m}. The Vernagtferner is unique in other ways, and the careful study of its characteristics will add greatly to our knowledge of glaciers.

Professors Forel and Richter have offered explanations of the

[1] The earlier reports appeared in this JOURNAL, Vol. III, pp. 278–88; Vol. V, pp. 378–83; Vol. VI, pp. 473–76; Vol. VII, pp. 217–25; Vol. VIII, pp. 154–59; Vol. IX, pp. 250–54; Vol. X, pp. 313–17; Vol. XI, pp. 285–88.

[2] *Comptes rendus du Congrès géologique international de Vienne* 1903, pp. 161–69.

apparent irregularities of glacier variations. The increase in snowfall in the reservoir results in a thickening of the upper part of the glacier, which thickening then progresses down the glacier, somewhat like a wave, more rapidly than the ice itself. The ice thus advances faster than it melts, and the glacier is pushed farther down its valley. When the supply in the reservoir diminishes, the pressure from behind also diminishes, and the ice moves less rapidly and melts back.

Professor Finsterwalder then takes up the study of an ideal glacier, subject to periodic variations of thickness at the névé line, and subject to uniform melting along its whole length; and finds a mathematical equation which represents the changes in thickness and length which the glacier undergoes. Although these conditions are not exactly those which a glacier experiences, still they are near enough to give results which correspond fairly well with what is actually observed. The solution of the equation shows that the glacier in advancing takes a steep slope in front and moves with considerable velocity, and during the retreat takes a very gentle slope in front and its velocity is much diminished. The variation in thickness at the névé line produces a much greater relative variation in the length of the glacier, and the change at the end occurs later than the change at the névé line. Under these conditions the glacier advances slowly and retreats rapidly. This is in contradiction to experience, as glaciers usually advance rapidly and retreat slowly. This contradiction probably comes from the fact that we have assumed a uniform variation at the névé line, which, however, is probably not at all regular, but makes a rapid increase and a slow diminution. If now we introduce a variable rate of melting, and assume that it has the opposite phase to the variation of thickness at the névé line, we find the variation in length increased and the state of minimum existing for a longer time, which Forel has described as characteristic of glaciers. It thus appears that the Forel-Richter theory is, in general, upheld by mathematical analysis; but there are many peculiarities which are still unexplained. In the observations of the Vernagtferner glacier very great variations of velocity were found without corresponding increases in thickness.

Lately Hess has shown that ice yields more rapidly to a given

force as the time of application of the force increases. This might explain some of the difficulties, but many difficult questions of glacier physics arise in this connection.

The International Committee serves as a natural point of union for all investigators of glacier phenomena, and is doing good work in encouraging glacier studies.[1]

The following is a summary of the eighth annual report of the International Committee on glaciers:[2]

REPORT OF GLACIERS FOR 1902.

Swiss Alps.—Of the ninety-five glaciers which are being observed, seventy-eight were measured in 1902. The great majority of them are in a state of recession, and it is probable that the 680 other Swiss glaciers are receding also. The recession is therefore general, though there is a slight tendency this year to advance, shown especially among the glaciers in the southwest Bernese Alps. The little glacier of Boveyre, which has been advancing for ten years as a result of a great increase in material due to an avalanche, has begun to retreat.[3]

Eastern Alps.—On the south side of the Ortler, two glaciers have retreated 3.5–11^{m}; one has probably made a slight advance. In the Silvretta group three glaciers show a retreat of 400–500^{m} since the last maximum in 1850–60. In the Oetzthal the Vernagtferner, which last year showed an advance of 50^{m} and a remarkable increase in velocity of from 210^{m} to 240^{m}, has suddenly decreased its speed to not more than one-third of its highest value; it has, however, advanced 20^{m}, and has swollen in its lower part. Its neighbor, the Guslarferner, has been stationary for many years.

[1] Professor Harry Fielding Reid, of Baltimore, was elected president of the committee for the ensuing three years, and M. E. Muret, of Lausanne, was re-elected as secretary. Professor Nathorst retired from the committee and was elected a corresponding member. Baron G. de Geer was elected to succeed him as representing the Arctic regions. Colonel J. von Schokalsky had already been elected to succeed the late Professor J. Mouschketow, who took such an active part in the work of the committee. The following additional corresponding members were elected: Professor Dr. A. Blümcke, of Nuremberg;; Professor Dr. Hans Hess, of Ansbach; Professor Dr. A. Penck, of Vienna; and Mr. George Vaux, of Philadelphia.

[2] *Archives des sciences physiques et naturelles*, Vol. XV, pp. 661–77; Vol. XVI, pp. 86–104.

[3] Report of Professor *Forel* and M. *Muret*.

Borings have been made in the Hintereisferner to determine its thickness. It has been completely pierced at a distance of 1,860^{m} from the end, where a thickness of 152.8^{m} was found. This glacier has retreated 94^{m} in the last eight years, and its velocity of flow has been reduced 25–30 per cent. Hochjochferner, near by, has retreated only 1^{m}, but has become somewhat thinner. Diemferner deserves special attention; it has advanced 30^{m} in the last two years, and 144^{m} since 1893. It has suffered a considerable change in form, and in the upper regions its sides very nearly reach the top of the old moraines.

In the same general neighborhood seven glaciers have retreated 6–20^{m} since 1891; and six others have retreated 21–90^{m} since 1899; two of these were advancing a few years ago. One glacier observed in the Stubai group is in continued retreat. In the Zillerthal the Schwarzenstein glacier is retreating, but more slowly than last year. The Horn Glacier has ceased to advance and has retreated 4^{m}, while the Waxegg has advanced 14^{m} on the average, and at one point 38^{m}. In the Venediger region eight glaciers show recessions of from 2–17^{m}. The Krimmlerkees, which shows the greatest retreat this year, was advancing last year.

In the Glockner group two glaciers have retreated 7–11.5^{m}, while the Pasterze is stationary.

In the Sonnblick group three glaciers show recessions of 5–20^{m} in two years. The Krummelkees, which advanced 7^{m} from 1899 to 1901, has been stationary since then.

In the Ankogl group two glaciers are retreating, but only half so fast as last year. On the other hand, the great Elendkees has changed its slight decrease of last year to a slight increase this year.

On the whole, the retreat is more rapid this year than in preceding years; nevertheless, a few glaciers are still advancing. We must mention that the Gepatschferner has been steadily retreating since 1886, when exact measures began.[1]

Italian Alps.—The Marmolada Glacier has retreated very considerably during the last forty years, though we cannot say what it is doing at the moment. The upper regions show signs of diminishing, but the growth before 1883 was made evident by the ice

[1] Report of Professor *Finsterwalder*.

closing up a grotto used as a sleeping-place by the Italian Alpine Club. This grotto remained closed from 1884 to 1900. The Cristal, Sorapiss, and Kellerwand Glaciers have all retreated from a fraction of a meter to 3^{m}. The snow-fields of Monte Cavallo show a considerable increase in size. The Lys Glacier, Monte Rosa, has retreated about 25^{m}, shows a marked change in its form, and reveals newly deposited moraines. In general, the retreat of the Italian glaciers has continued, but the snowfall has increased.[1]

French Alps.—Many glaciers have been observed under the direction of the French Committee on Glaciers, with the following results: On Mont Blanc the Bossons has greatly diminished; and the Mer de Glace, stationary for some time, now shows a marked recession.

In the Maurienne eleven glaciers are retreating; one has been stationary since 1892. The Glacier des Sources de l'Arc has retreated 1,250^{m} horizontally and 300^{m} in altitude since 1873. In the Grandes Rousses the Glacier des Quirlies has retreated about 25^{m} since 1899, and the Grand Sablat about 35^{m}. The Glacier de la Selle has retreated 600–800^{m} in the last thirty years. The Glacier des Étançons has retreated greatly, probably 100^{m} in the last fifteen years. Of its two tributaries which are now separated, one is advancing and the other is retreating.

The Pyrenees.—The advance of the end of the nineteenth century has affected the Glacier de Vignemale, which has inrceased notably in thickness, though it has not advanced. The glaciers, in general, are distinctly retreating. Of the twenty observed, fifteen are retreating, and the others are either stationary or possibly growing, although none show any real advance from 1901 to 1902.[2]

Scandinavian Alps: Norway.—The summer of 1901 was particularly warm in Norway, so that the glaciers melted rapidly, and the snow-fields diminished to an extent never before seen. Many glaciers were retreating, and the glacial streams were much higher than usual. On the other hand, during the summer of 1902 the snow remained very late. Several glaciers of Galdhötind advanced 15–20^{m}, and several receded, perhaps as much. On August 11, the glacier lake of Mjölkedalsvand was suddenly emptied and caused an inundation. Two glaciers near Olden are retreating.

[1] Report of Professor *Porro*. [2] Report of Professor *Kilian*.

In the neighborhood of Folgefon several glaciers were retreating rapidly in the summer of 1901, whereas in 1902 they were advancing.

Sweden.—The Mika Glacier has advanced 5^{m} since 1901, and the Solta 20^{m} since 1900. The Skuova has apparently been stationary since 1897.[1]

Polar regions.—An expedition was sent to Greenland to study the inland ice between latitudes 68° 30′ and 69° 20′. Surveys of the Jakobshavn Fjord and the border of the inland ice to the south were made on a large scale. Photographs were also taken from marked points which may be used for future comparison. All the glaciers of the Jakobshavn Fjord are notably retreating; the rocks for 5.5^{m} above the present surface of the large glacier are entirely free of lichens, and the tongue of the glacier is 4^{km} shorter than in 1883. The small glaciers flowing from the tributary fjords of the Jakobshavn show a similar, but smaller, retreat. Farther south, near Orpigsuit, the edge of the inland ice seems to be retreating, as the rock immediately above it is free of lichens and is covered with fresh striæ. Photographs of the nunataks were taken which will serve to determine future variations.

The Swedish expedition to the South Pole visited Royal Bay in the Island of South Georgia. Ross Glacier, which had retreated, according to the German South Polar Expedition, 800–900^{m} between 1882 and 1883, has since then advanced to the point where it stood in 1882.[2]

Himalaya.—The Taschiny Glacier in Kashmir was retreating in 1875 and advancing in 1886. Some small glaciers in the Panjal Range were retreating before 1884 and advancing slightly some years later. In the Nun Kun the glaciers were advancing in 1902.

In the Karakorum Range several glaciers in Schigar Valley advanced for eight or ten years before 1895. In the Saser-Nubra Mountains a slight advance took place in 1896.[3]

Caucasus.—The four glaciers on Mount Kazbek which have been retreating for some time have become stationary, and great accumulations of snow seem to indicate the beginning of a new advance. The summit of Kazbek, which in 1900 was almost free of snow, is now covered to a considerable depth. In the valley of the Guisel-

[1] Report of Dr. *Oyen.* [2] Report of Dr. *Steenstrup.* [3] Report of M. *Chas. Rabot.*

Don the Djimara Glacier is still retreating, as are also two glaciers in the valley of the Ouroukh. The Mayl Glacier, on the northern slope of Mount Kazbek, was the scene of two terrible outbreaks which destroyed the baths of Kermadon in July, 1902. Two avalanches, originating in seven large snow-fields, came down a lateral gorge, and then passed over the surface of the glacier, following a course six miles long. The slopes of the mountains are not steep enough to cause this catastrophe, and it is probable that it was induced by an earthquake.

Siberia.—A number of small glaciers exist near the sources of the Oka River in the mountains southwest of Lake Baikal. Some of these were described by M. Radde in 1885. They are at present much smaller than they were then, and one of them seems to be on the point of disappearing. The Alatau or Kuznezk Mountains, 200 or 300 miles north of the Altai, do not contain any glaciers at present, but they show traces of former glaciation in the smoothed rocks and large moraines. In the Alatau of Sungaria there are many glaciers; those on the northern slope being generally larger than those on the southern. Two of the former have been surveyed. The mean height of the peaks in this portion of the range is about 13,000 feet. There are many glaciers in the Tyan Shan mountains which are rarely visited. The peaks of this chain have altitudes of from 16,500 to 17,500 feet; a new determination of the height of Mount Khantengri makes it 22,600 feet. Some of these glaciers are in a marked state of retreat; others do not indicate any definite variations. It seems in general that, if the glaciers are decreasing, there must be shorter intervening periods of growth, at least for some of the glaciers.[1]

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1903.[2]

In May, 1903, the Muir Glacier was visited for the first time since the earthquake of 1899. Mr. C. L. Andrews, deputy collector of customs at Skagway, and Mr. Case went from Skagway to the Muir Glacier in an open boat, photographed the end of the ice,

[1] Report of M. *Schokalsky*.

[2] A synopsis of this report will appear in the *Ninth Annual Report* of the International Committee. The report on the glaciers of the United States for 1902 was given in this JOURNAL, Vol. XI, pp. 287, 288.

and showed by a map the changes which have taken place there. They found that the ice-front had retreated to a distance of from 3 to $3\frac{1}{2}$ miles from its former position, and almost the whole inlet was covered with floating ice very closely packed together. The ice-front now passes from the base of Mount Case northwesterly to the two small nunataks opposite, which have become united into one by the lowering of the ice. It then passes southwesterly to the corner of the large nunatak which separates Morse Glacier from the Muir. An area of $4\frac{2}{3}$ square miles has thus been taken from the glacier and added to the inlet. An area of 9 square miles of the inlet is closely covered with floating ice. The amount of ice which has been broken off from the glacier—if we assume an average thickness of 700 feet, which is probably not far wrong—amounts to about 91,000 million cubic feet. This is about fourteen times the amount formerly discharged annually into the inlet.[1]

The ice forms a terrace along the eastern side of the mountains, and Dirt Glacier ends as an independent tide-water glacier. Morse Glacier, which had already become an alpine glacier, separated from the Muir, no longer has its valley closed up by the latter's ice.[2]

The new ice-front is composed of two parts. The eastern part from Mount Case to the nunatak consists of ice which is practically stationary, whereas the western part receives all the active flow of the glacier. This portion does not differ materially in breadth from the old ice-front, and receives practically all the ice which was formerly discharged into the inlet. It stands up as a vertical wall probably about 200 feet above the water. In 1890 the surface of the ice where the glacier now ends was 500–600 feet above sea-level, so that this surface has been lowered 300–400 feet. The fact that the ice stands up as a vertical wall makes it probable that the water is fairly deep at this point, though probably not as deep as at the old ice-front. If this is so, the velocity of the ice near the present end is probably a little greater than near the old end, as the section is somewhat less. This causes a tendency to advance, but the position of the end will probably remain almost stationary for some time; for if it advances materially beyond its present position, it will find no

[1] "Studies of Muir Glacier," *National Geographic Magazine*, Vol. IV (1892), p. 51.

[2] C. L. ANDREWS, "Muir Glacier," *ibid.*, Vol. XIV (1893), pp. 441–45.

support on the east; it will broaden out, and will offer a longer line for breakage. If, on the other hand, there should be any material retreat, the ice-front would again become longer, resulting in still more rapid retreat, until, perhaps, the glacier withdraws above tide-level.

There are eight glaciers of considerable size within easy reach of Skagway. These glaciers have been under observation by Mr. Andrews, who expects to continue to observe them. They are all retreating rapidly. Denver Glacier melted back 40 feet in two months in the summer of 1903. The "S" Glacier and the Upper Glacier have been retreating at the rate of 30 or 40 feet a year since 1898 (*Andrews*).

The Mendenhall Glacier near Juneau retreated at the rate of 40 or 50 feet annually between 1892 and 1901. Immediately bordering its sides and end the ground is free of vegetation, but the shrubs and trees gradually increase in extent and size as we go farther from the glacier, either down its valley or up the mountain side. This increase in the age of the trees indicates the rate at which the glacier has retreated. It is very remarkable how rapidly trees have grown in this region, attaining a thickness of nine inches in twenty-five years and of nearly two feet in one hundred years[1] Mr. Fernow has also noted the remarkably rapid growth of trees at the entrance of Glacier Bay, where trees only forty or fifty years old were 36 inches in diameter and 80 feet high.[2]

Throughout Oregon and Washington the last three years have been marked by excessive precipitations, and the snowfall of last year seemed to be the greatest of the three; but there is no evidence that this has yet resulted in the advance of the glaciers. Mount Baker is an interesting mountain, but it has received very little attention. It was ascended last summer by Mr. C. E. Rusk, who writes me that there are about ten glaciers on the mountain. Two of these, which he had the opportunity to examine, showed signs of marked retreat in recent years.

The Eliot Glacier on Mount Hood has retreated slightly since

[1] MARSDEN MANSON, "Forest Advance over Glaciated Areas in Alaska and British Columbia," *Forestry Quarterly*, Vol. I (1903), pp. 94–96.

[2] See *Harriman Expedition*, Vol. II, pp. 249–52.

1901. (*Langille.*) The glaciers on the south side of Mount Hood also show evidence of retreat during the same interval. (*Montgomery.*)

There are two or three glaciers on Mount Jefferson, but we have no evidence as to their variations. The peaks of the Three Sisters surround a large amphitheater five miles wide, which opens toward the east and formerly held a large glacier, but this has shrunk so much that it has now broken up into four small glaciers. There are three others on the outer slopes of the mountain. The moraines of the glaciers in the amphitheater stand up 30 or 40 feet above their surface. They are still fresh and free of vegetation, showing that this diminution of the ice has taken place in comparatively recent years. The reduction in thickness of the ice seems to be more marked than the reduction in length. Ice still remains under the moraines, which is a further indication of the short time since they were formed. The double crests which some of these moraines present are ascribed to the melting of the ice under them. One of these glaciers showed in its Bergschrund projecting layers of ice separated by layers of dirt similar, on a small scale, to the projecting layers of ice found at the end of Greenland glaciers.[1] In the present instance, however, these projections are not ascribed to shear, but to differential melting; for where the snow is shaded from the sun the projections do not exist. (*Russell.*)

Comparison of photographs of Lyell Glacier in California taken in 1883 by I. C. Russell and in 1903 by G. K. Gilbert show only very slight recession, whereas the McClure Glacier, close by, has suffered a marked retreat during the same interval. (*Gilbert.*) This difference may be due in part to the shapes of the two glaciers, Lyell being much broader than it is long, whereas the McClure presents a definite tongue.

Professor LeConte has found a new glacier just below the eastern precipice of Mount Jordan, in northern California, and thinks that there are other small glaciers along the eastern slope of the Sierras in this neighborhood. There has been less snow in the Sierras

[1] I. C. Russell, "Glacier Cornices," Journal of Geology, Vol. XI (1903), pp. 783–85.

of California this year than for many years past, and probably all the glaciers are retreating. (*LeConte.*)

The Chaney and Sperry Glaciers in Montana show a marked retreat. The former, though a small glacier, has retreated 200 yards or more in the last eight years. (*Chaney.*)

The snowfall on the Arapahoe Glacier in Colorado was unusually small in 1902. In 1903, however, it was unusually large, and seems to have produced a noticeable effect on this little glacier. The ice is somewhat thicker and the front slope of the glacier steeper, but there is no apparent change in length, except at two points where streams have effected a slight recession. From September, 1901–2, the precipitation was below normal and the temperature above normal at the Weather Bureau stations nearest to this glacier, whereas it was just the reverse from 1902–3. Silt was found on the moraines similar to that found last year, and as it is impossible to suppose that the glacier has advanced over the moraine and retreated again within a year, the former explanation of this silt, which required rather violent fluctuations of the glacier, must be abandoned. It is probable that the silt is due to dust blown from the mountains upon the snow and left on the moraine when the snow melted. This is a more satisfactory explanation, but it shows nothing with regard to the glacier changes.[1]

HARRY FIELDING REID.

GEOLOGICAL LABORATORY,
John Hopkins University,
March 17, 1904.

NOTE.—Since the above report was written, the third volume of the Harriman Alaska Expedition, on *Glaciers and Glaciation*, has appeared. It is written by Mr. G. K. Gilbert, and is a valuable contribution to our knowledge of the Alaskan coast glaciers. Mr. Gilbert collates all information regarding the variations of these glaciers up to 1899, and adds the observations made by himself and by other members of the expedition. The positions of the ends of many glaciers are shown by pictures and maps. The glaciers discussed are too numerous to be named here, but we must mention the general fact that the glaciers of Glacier Bay and of Disenchantment Bay show very great recessions during the last hundred

[1] JUNIUS HENDERSON, "Arapahoe Glacier in 1903," JOURNAL OF GEOLOGY, Vol. XII (1904), pp. 30–33.

years, whereas those of the southwestern slopes of the Fairweather Range and those of Prince William Sound have quite lately been as extensive as they have probably been for several centuries. Mr. Gilbert makes some general suggestions of a theory to explain such curious anomalies. He also presents clearly the very striking evidence which the topography of the Alaskan coast offers in favor of the power of glaciers to erode their channels. The volume concludes with a theoretical discussion of the influence of the sea on the pressure which tide-water glaciers exert on their beds below sea-level.

FAREWELL LECTURE BY PROFESSOR EDUARD SUESS ON RESIGNING HIS PROFESSORSHIP.[1]

In the last lecture we occupied ourselves with the structure of South America. We saw that the earlier volcanic occurrences are restricted entirely to the Cordillera of the Andes, but that in the course of their appearance there are long interruptions.

We have therefore arrived at the close of our hasty survey of the earth's entire surface, and today we will review the events which have been set forth during the last two semesters. The present lecture, moreover, also closes my active life as a professor, and I stand at the end of a career of teaching at this university, which I have been permitted to enjoy for eighty-eight semesters. Before I take up the short summary mentioned, I believe it suitable to say a few words in regard to the changes which our science has undergone during this long period.

My collegiate work as lecturer on general paleontology was begun October 7, 1857—two years before the appearance of Darwin's book, *The Origin of Species.*

It is well known that in the eighteenth century prominent thinkers, as Leibnitz, Herder, and others, properly recognized the connection and unity of all organic life. But, at the beginning of the nineteenth century, Cuvier, essentially by means of the fossils of the chalk of Montmartre, was able to present the surprising evidence that there had lived on the earth genera of animals which today are wholly extinct, and that similar changes have again and again occurred in the animal kingdom. He thus concluded that there had been repeated revolutions. In this he was followed by the great majority of inquirers, and at that time—the year 1857—everyone was completely under the influence of Cuvier's views. Personally, a paper by Edward Forbes, on the influence of the glacial period on migrations, had a great effect on me; the article merits reading even to this day.

[1] Given July 13, 1901, in the Geological Lecture Hall, Vienna University; taken stenographically by Mr. H. Beck. For the original lecture, in German, see *Mitth. Pal. u. Geol. Inst.*, Universität Wien, 1902, pp. 1–8. Translator, Charles Schuchert.

After the appearance of Darwin's book, there occurred a great and general change of view in all branches of biology. In fact, outside the great discoveries of Copernicus and Galileo, there cannot be cited another example having so deep an influence on the general opinions of naturalists. Darwin was not the first to conceive and pronounce upon the unity of all life; but that he was able to produce stronger proofs and to direct the trend of thought constitutes his undying fame.

In the field of paleontology the consummation of this change did not, of course, go on so simply and, at least with us, so entirely in accordance with the views of Darwin as one is apt to imagine. The Darwinian theory of the variability of species was essentially based on selection and related appearances. Paleontology, however, teaches otherwise. It teaches that the terminology for single divisions of the stratified terranes, characterized by their fossil remains, finds application over the entire earth. Therefore from time to time there must have occurred, in some way, general changes affecting the entire physical condition of the world. Nor is there seen a perpetual and continuous changing of organic beings, as would be the case through the constant influence of selection. On the contrary, there are entire groups of animals appearing and disappearing. Darwin sought to explain this by means of gaps in our knowledge, but today it is known that these supposed gaps possess too great a horizontal extension.

There now arises the thought that the changes in the outer conditions of life have a controlling influence. I may here state that on this question there was some correspondence between Darwin and our widely mourned Neumayr, and that Darwin in no wise took a dissenting stand against the objections. In this connection it is most remarkable that the great and general knowledge of paleontology which I have just indicated, should apparently have made upon so great a mind as Darwin's less of an impression than those small lines of variation noticed in certain fossil fresh-water snails, as, for example, in *Valvata* or *Paludina*.

Here and there conditions are combined which permit somewhat closer analyses of the relations of this subject. This for instance, is the case in the superposition of the Tertiary land faunas of Europe,

more particularly of Vienna. Here one recognizes the following: Living beings are dependent, on the one hand, on certain outer physical circumstances, as climate, moisture, etc.; on the other hand, they also are mutually and socially dependent upon one another. Every living province—or, as it is usually expressed, every zoölogical province—forms, as it were, an economical unity in which for so many flesh-eaters there must be so many plant-feeding food animals; for so many plant-feeders, so many food plants; honey-sucking Lepidoptera presuppose flowers; for insect-feeding song-birds a certain number of small insects are necessary, etc. The disturbance of one member of this unity can possibly destroy the balance of the whole.

According to all appearances, such disturbances have occurred from time to time in land faunas, and they may have been of very diverse kinds. Then again an entire fauna is seen to vanish over all Europe, or over a still greater region, and a new fauna comes in to take its place. This new fauna nevertheless always has a more or less strongly vicarious relationship to its predecessor; it is clearly a variation of the former, probably in the main a resulting adaptation to changed conditions; and even if the sequence of strata were completely unknown, one could readily discern which was the first, the second, or the third fauna.

Besides this, the numerous phylogenetic lines which unite nearly all the great groups of fossil animals; or the unity in the developmental nature of single organs, as the extremities; or the general superposition of gills and lungs; or the rows of striking harmonies that exist between the development of certain groups of animals, and of single individuals of these groups—all indicate with certainty the correctness of the Darwinian basal idea, namely, the unity of life.

Stratigraphic geology and paleontology show that the evolution of organic life was probably never completely interrupted, but that it did not go on in a uniform manner. Disturbances have occurred. The struggle for existence continues; yet it is only of secondary importance. Single very old types, as *Hatteria* (*Sphenodon*), have continued to maintain themselves to our day with but slight changes.

Allow me now to speak of a few tectonic questions.

When I began my collegiate work, there prevailed, especially in

Germany, the idea that mountain chains were built symmetrically; one group of oldest rocks formed the lifted or lifting axis, and upon each side were arranged younger rocks in parallel zones. Thus, you will still find in my own writing on the substructure of Vienna, in the year 1862, a presentation of the Alps as symmetrical mountains.

Of course, this idea did not prevail without objections. At nearly every gathering of German naturalists at that time, the old Bergrath Dücker arose to protest against it. No one listened to him. With Schimper it was the same. The authority of Leopold von Buch, who expressed himself for symmetrical construction, remained unshaken. Then Leopold von Buch died. Upon this primary question of modern geology you will find no explanation for the origin of mountains in the leading text-books of that time, as, for instance, Lyell's justly celebrated *Principles of Geology*.

For the investigation of this problem no part of Europe was more advantageously situated than Austria. There the land is arrayed before us in unusual variety. Hardly anywhere in Europe are tectonic contrasts so plainly presented—contrasts between the Bohemian Mass and the Alps, between the portion of Russian table-land beneath the Galician plain and the Carpathians, the peculiar connection of Alps and Carpathians, the continuance of the Turkestan depression over the Aral Sea into the depression of the Danube and to Vienna, and much besides. In the year 1857 the idea was still often maintained that the deposits found in the eastern Alps did not occur at all outside of the Alps, so great were the difficulties which the application of the accepted stratigraphic divisions of England and south Germany bore to the strange occurrences in the Alps themselves.

Soon, however, it was recognized that in the Bohemian Mass the stratigraphic sequence was far less complete than in the adjoining regions of the Alps, and that in Bohemia particularly there is an extraordinary interruption of marine deposits extending upward into the Middle Cretaceous, whereas in the Alps all these great epochs are represented by marine strata. This same transgression of the Middle and Upper Cretaceous shows again in Galicia, then far into Russia, on the other side of the French Central Plateau, on the Spanish Meseta, in large parts of the Sahara, in the valley of the Mississippi, and northward over this region to the vicinity of the Arctic Sea, in

Brazil, finally on the shores of central and southern Africa, in east India; and, in fact, over such extraordinarily vast regions that it became impossible longer to explain such transgressions of the sea, according to the older views of Lyell, by means of the elevation and depression of continents.

Through this and similar observations the newer idea has recently come into prominence that some general change must have occurred either in the shape of the hydrosphere or in its entire volume. It was seen that by the forming of a new oceanic depth, due to sinking, a certain amount of the hydrosphere was drawn off into the new depression, and that at the same time there appeared to be a general land elevation, or, more correctly, there must have resulted a general sinking of the beach lines. The older view of the numerous oscillations of the continents has also given way more and more to the teachings of marine transgressions, and through the denudation of continents, a more exact examination into the actual mountain movements has become possible.

If one were to assert that the Alps are folded, but that the Bohemian Mass is not, and that because of this there has resulted a damming up, then this assertion would not be exact. The Bohemian Mass is also folded, and there is at present no known portion of the earth's surface of which at least the archaic base is not folded. The difference, however, consists in this, that the folding has ended early at certain places; at others it has continued into a later or very late time, and possibly has also continued with a change in the ground-plan.

In this respect central Europe shows a quite peculiar arrangement. The oldest folding is seen in the gneiss of the western Hebrides. Younger and of pre-Devonic age are the folds of the Caledonians, which can be traced down to Ireland. On these, farther south, are ranged the Armoricanian and Varischian folds, which embrace southwestern England, Normandy and Brittany, the Central Plateau, the mountains of the Rhine, and the Bohemian Mass, inclusive of the Sudetes. Its principal folding was accomplished before the close of Carboniferous time, but minor movements of various kinds have followed. The Alps and Carpathians even underwent decided folding in the Miocene. Each part has moved northward toward the pre-

ceding, or toward the horsts, in which the earlier member was dissolved by sinking, and thus Europe has resulted through a succession of younger and younger folds.

Meanwhile, more and more light came regarding the strange development which certain Mesozoic deposits, particularly the Triassic of the Alps, show when compared to the north-lying lands, as Würtemberg or Franconia. The observations in Asiatic highlands, especially in the Himalayas, taught that this type of Triassic development has a very wide distribution toward the east; and it even became possible to prove that directly across present Asia, from the existing European Mediterranean to the Sunda Islands, there once extended a continuous sea. This sea has, as you know, received the name Tethys. The old continent along its southern side was named Gondwana Land, and that on its northern side, Angara Land. The present Mediterranean is a remnant of Tethys.

This Mediterranean, however, consists of a series of areas of diverse construction, and we have had opportunity to convince ourselves that, since Middle Tertiary time, first a portion was separated, as, for instance, the Danube plain, then a portion was added, as the Ægean Sea.

The progress of geological research during the last ten years, however, has been so extremely great that a far more extensive knowledge of the seas has become possible. They are of different kinds. We examine a world-map, and thereby, in accordance with oft-repeated warning, seek to guard against the deception which the distortion of Mercator's projection so easily produces. We see that, with the exception of the two Chinese rivers, Yang-tse-kiang and Hoang-ho, hardly another great stream finds its way to the Pacific Ocean. All waters of the continents flow toward the Atlantic or Indian Ocean. Many years ago the Russian General von Tillo drew on a little map the watershed of the earth, and showed how surprisingly small an amount of fresh water the Pacific receives.

These two oceanic areas differ also in a feature of far greater importance. At the beginning of these lectures I noted the remarkable fact that from the mouth of the Ganges eastward to Cape Horn the continents are bounded ocean-ward by long arcuate mountain ranges, all of which appear to be moving toward the Pacific Ocean.

When, however, one follows the coast from the mouth of the Ganges westward, and again to Cape Horn, totally different conditions are met. Disregarding the bending of the mountains at Gibraltar and vicinity, which the American Cordilleras in the Antilles also show—at both places, as you know, folded mountain chains do approach the Atlantic area, but they bend backward as if held back by some secret force—one sees encircling the Atlantic and the Indian Oceans only similar amorphous coast lines, namely, such as are in no wise predicated by the structure of the lands. Therefore we have distinguished a Pacific and an Atlantic type of coast.

We can go still farther. In whatever direction one proceeds from the land to the Pacific, an unfolding sequence of marine series is seen. If one goes from the wide Archean areas of South America, on which lie horizontal Paleozoic sediments, toward the west, in the Andes are found marine beds of the Jura, the Lower Cretaceous, also the Middle and Upper Cretaceous. It is the same if one goes from the old Laurentian Mass in Canada westward toward the sea. This is also the case in Japan, etc. From the foregoing we may conclude that the Pacific is of very ancient origin, and that it has existed for an extraordinarily long time.

With the other oceans it is different. When one nears the Indian Ocean, horizontally disposed marine beds are met with, not folded strata as in the Pacific area. These, however, do not begin with the Trias, but in east Africa as in western Australia start with the Middle Jura, and in Madagascar with the Middle Lias. Similarly, on the shores of the Atlantic Ocean horizontal non-folded strata are found, and these, in west Africa as in North America and Brazil, begin with the Middle and Upper Cretaceous. From this we conclude that the Pacific Ocean is older, the Indian Ocean younger, and the Atlantic Ocean essentially still younger.

I have mentioned yet another ocean, Tethys, which in Mesozoic times lay across present Asia, and whose remnants constitute our Mediterranean. The entire area of Tethys is laid in folds, and from the Pacific Ocean to the Caucasus throughout these folds are also moving southward; their margins in the south are overthrusted; the entire province of the sea is crushed from the north, and even remnants of the old southern foreland—the Gondwana Land, or the

Indian peninsula—are included within this folding. You have heard that Kinchinjinga and its neighbors, the highest peaks of the earth, though within the folds of the Himalayas, still have, so far as known from their foothills, the stratigraphic sequence of Gondwana Land.

We will now take a glance at the distribution of the lines of folding on the earth's surface. In the region of Lake Baikal lies an extensive, somewhat crescentically arranged mass of very ancient Archean rocks. It is folded, with a nearly northeast strike in the east and a northwest strike in the west, and the folds are of pre-Cambrian age. This old strike locus or vertex embraces Sabaikalia, northern Mongolia, and the East Sajan. Farther northwest there is developed another, younger vertex, or a second center of folding—the Altai. From this second younger locus proceeds an extraordinarily great system of bow-shaped folds, which, in an almost incomprehensible manner, embraces the entire Northern Hemisphere. The Altai encircle the old vertex, and its bows repeat themselves in the east from Japan and Kamschatka to the Bonin Islands. Toward the west they form the broad ranges of the Tian-shan and Bei-shan. Their southeastern branches appear in the bows of Burmah. In front of them to the south lie the marginal bows of the Himalayas—the Iranic; and farther along, the Tauric-Dinaric bows. They press over the Caucasus to Europe, and form here the two previously mentioned chains of folds.

These two chains of folds are themselves preserved in different ways. The one, older, embracing the Varischian and Armoricanian folds, is first discernible in Mähren. It reaches the Atlantic Ocean in southwestern Ireland and Brittany, and disappears as a Rias coast. Years ago, however, Marcel Bertrand called attention to the fact that such a broad and mighty mountain system—on the Atlantic coast it is as broad as the bows of the Himalayas—could not possibly suddenly end here, but that in all probability it is continued to the other side of the ocean in the Rias coast of Newfoundland. As you have heard, Marcel Bertrand accordingly continued the Armoricanian primary lines directly across the ocean to the Appalachians.

Of the Appalachians, however, it has been learned in recent years that they are far longer than was formerly believed. They form a bow which is not, as in the Asiatic and European chains,

folded toward the convex side, but toward the concave side, first westerly, then northerly, and continues west of the Mississippi into the Washita Mountains.

The second or younger type, the Altai, strikes with decided flexing, narrowed through older horsts, from the Balkans to the Carpathians and the Alps, and at Gibraltar the latter join those bows of the western Mediterranean that are completely reversed.

Let us return once more to North America. As we have heard, the American term as Laurentia the wide Archean area which embraces the region of the Hudson Bay, middle Canada, and the central part of the United States. The Appalachians to the east and south of this mass, as we have seen, have a concave strike, are folded toward Laurentia, and vanish in the Washita hills. West of Laurentia, also, it is similar. It could have been shown that the Cordillera, whose connection with northern Asia has of course not yet been established, is, on its eastern side, in Canada, also folded toward Laurentia. It, too, bends toward the south with a more and more concave strike; continuing through Mexico, it is folded to the northeast, and then part of its folds finally turn toward Cuba and in the direction of the Antilles.

Thus on both sides is North America encircled by concave-striking chains of folds. It is as if the folds extended away from Asia and toward Laurentia. This entire grand phenomenon may be illustrated by a comparison. By the eruption of Krakatoa the oceans were moved; long waves proceeded from the place of eruption, traveled around the entire earth, and met themselves on the other side of the sphere. This is merely a comparison, not an explanation.

In the Southern Hemisphere the state of things is wholly different. For some time it has been known that in East India and South Africa, during Permian and Trias time, there flourished identical land floras—the Gondwana floras. Accordingly, it is concluded that these two continents were once united, and the area was named Gondwana Land. Later such floras were also found in Australia; then in the Argentine Republic. Thus it spread around the south. But the conclusion drawn from this as to the continuity of so great a continent was shattered by the circumstance that not only the

characterizing plants of Lower Gondwana, but, in addition, the South African occurrences of associated animals, were also found in the Permian deposits of Perm in north Russia.

What then results is an exceedingly similar distribution of land plants and land animals of that time, and a great continent in the south; yet immediate proof of its continuity is lacking.

In fact, only on the Pacific margins of this supposed or actually united continent is it found that folding has taken place, and, indeed, in the east of Australia and the west of South America; while the intermediate Atlantic and Indian coasts are without younger folds. It is true that more recently, folding of pre-Carboniferous time has been described in South Africa, but in general the entire area between the western South American Cordilleras and the eastern Australian Cordilleras appears dead and unmovable. This is in contradistinction to the great diversity in movements of the Northern Hemisphere.

In general, these are the chains which we have sought to follow in detail in the course of these two semesters. The attempt toward a geometric arrangement of the mountain chains, which recently has been undertaken by distinguished specialists, finds, I fear, but little confirmation in actual occurrences. The tectonic lines that are met in nature tend generally at most to follow straight lines only in fissures or faults. The foldings, however, maintain themselves more like long waves, and they give way to the older horsts. This is seen more clearly in the youngest Alps, or that branch of the Altai trending toward Europe; the bows of the Banda Islands are similar.

I should now like to say a little about the conditions of life upon the earth. We have already spoken of the wide distribution of the land faunas and land floras of Lower Gondwana. Earlier types of Carboniferous land floras had spread themselves from the Arctic region to South Africa. The Culm flora is known in Europe, Mongolia, and Australia. Still more noteworthy is the fact that in the basalt streams of western Greenland there are interbedded plant layers of Lower and Middle Cretaceous, as well as of Tertiary times, and that during all this period there lived in this Arctic region first ferns and then leaf-bearing trees. In a word, in west Greenland

are seen occurrences of different times which throughout cannot be brought into harmony with the climatic conditions of the glacial period nor with those of the present; thus this entire younger epoch appears as an exception. One gets the impression that not at all times did there exist the present diversity of climate, and also that the diversity of life was not at all times a varied one. The great Indian land fauna of today, with its tigers and elephants, can be considered as an independent unity, but here and there it is accompanied by older Malayan remnants which increase the diversity.

Gentlemen, as you see by this attempted survey, I can point out only some of the various directions in which our studies may be continued, and there exist so many hundreds and hundreds of questions that all, even the keenest ambition, will find the portals open and may hope for satisfaction. New discoveries are in prospect for all conscientious inquirers.

In the course of the years I have seen and experienced much. In the beginning a man has honestly to endeavor with zeal, and with certain restrictions upon himself, to learn the detail; and sometimes the hair whitens before he is in a position to obtain a general view and to risk a first synthetic attempt. This first step to synthesis is, however, the deciding step in the life of the inquirer. Soon he notes that his judgment obtains more consideration among his colaborers; he becomes more careful and conservative with the same; and finally the hour arrives in which his soul is filled with the highest satisfaction, because he has been able to add to human knowledge some new view or a new fact—a feeling over against which everything naturally vanishes that the outer world is able to offer in acknowledgment.

Bulwer Lytton says in his novel: "When a man of great age is surrounded by children, he then sees at the end of his days, not a period, but only a comma." This applies in equal measure to the inquirer and to his students. This is my good fortune, which today becomes my portion.

Many have departed from us. The dumb tablets in our collection halls give their names, and it is our duty today to remember them gratefully. Stolizcka found his end on Kara-Korum, Lend on Kilima-ndjara, Foullon on Gaudalcanar; Rodler brought his death

germ from the Bachtyari Hills; we all think of Oscar Baumann with admiration.

I rejoice today with all my heart that I am enabled to greet, not a series of students, but generations of students, from the renowned gray-haired members of the Royal Academy to the young fellows with sharp eyes.

To the young ones among you I should at this moment like to say another word. The old ones know it already. In the course of these forty-four years much has occurred on the earth, but nothing at this time so penetrating, nothing so decisive for the entire culture of humanity, as progress in the natural sciences. Into all departments of human life and doings it has entered; it influences and changes our social conditions, our philosophical conclusions, our political economy, the strength of states, everything. He who will look closer, however, can perceive that, besides the natural sciences, the naturalist himself is coming more and more to the front, that his social significance is being recognized, and that the worth of his studies is being more valued.

Accordingly, the growing generation of inquirers has an increased duty, which consists in this, that the ethics of their personal life shall become more precise, so that, by the increasing influence of naturalists on all social and state life, the naturalist will also feel himself more worthy to take part in the guidance of intellectual humanity.

And now I have reached the comma. When I became a teacher, I did not cease to be a student; and now that I cease to be a teacher, I shall not cease to be a student so long as my eyes see, my ears hear, and my hands can grasp. With this wish, I therefore do not step out, but take up my former position.

And now I thank you all from the depths of my heart for your presence, and beg of you to retain for me a friendly remembrance.

Editorial.

The recent publication by the United States Geological Survey of monographs on the Mesabi, Vermilion, and Menominee iron-bearing districts marks the approximate completion of a prolonged and systematic study of the great Lake Superior ore-bearing series and of the associated pre-Cambrian formations. There is yet to appear a supplementary and final volume on the geology of the Lake Superior region as a whole, which will bring together and correlate the general conclusions and maps of the district monographs. It is understood that this will be submitted for publication in 1905.

This notable series of reports was formally inaugurated in the late eighties by Dr. R. D. Irving, but was prefaced by his work on the Wisconsin survey in the seventies and early eighties. Dr. Irving's death in 1888, however, permitted him to see only the beginning of the monographic work in the Penokee-Gogebic district. The further execution of the plan fell to his associate, Dr. C. R. Van Hise, who, during the past sixteen years, has carried it forward to its present advanced stage. The first of the monographs to appear was the Penokee-Gogebic monograph, No. XIX, published in 1892. The field work for this was done jointly by Irving and Van Hise, but the writing of the monograph fell largely to the latter. In 1895 appeared the Marquette monograph, No. XXVIII, by Van Hise in collaboration with Professor W. S. Bayley. This was followed in 1899 by the appearance of the Crystal Falls monograph, No. XXXVI, by Professors J. Morgan Clements, H. L. Smyth, W. S. Bayley, and C. R. Van Hise; in 1903, by the Mesabi monograph, No. XLIII, by Dr. C. K. Leith; and finally, during the past winter, by the Vermilion monograph, No. XLV, by Clements and the Menominee monograph, No. XLVI, by Bayley, the latter having just come from the press. Monograph V, on the copper-bearing rocks of Lake Superior, by Irving, should also be mentioned, although it was published before (1883) the inauguration of the plan for the comprehensive investigation of the iron-bearing districts.

The total expenditure of the survey for this great series has been less than $150,000. Considering the magnitude of the iron-mining industry, and the intricacy and importance of the geological formations involved, the expenditure is very conservative. Larger sums than this, we are reliably informed, are spent by single mining companies in the Lake Superior region in the exploration of very limited areas; indeed, it is in a large measure due to the co-operation of such companies that this series of monographs has been prepared within the amount named.

The work of the survey is highly appreciated in the Lake Superior region, where a good geological and structural map has come to be regarded as an absolute prerequisite to intelligent underground exploration and mining development. The working maxim has been firmly established that before expensive underground exploration is attempted it is economy to spend whatever is necessary—which is usually a comparatively small amount—to ascertain all that can be learned at the surface. A proper geological map of the ore-bearing district saves many thousands of dollars in sub-surface exploration by limiting the areas which it is worth while so to explore. Professor Irving and his colleagues mapped in detail the iron-bearing formation of the Penokee-Gogebic district in the later seventies and early eighties, and up to the present time no ore-bearing areas have been found outside the narrow limits they laid down. While elsewhere, from time to time, exploration has enlarged the boundaries of the ore-bearing formations mapped by the earlier surveys, it is within limits to say that a vast amount of subsurface exploration which might otherwise have been done in barren areas has been localized in more promising fields by means of the geological maps.

This series of monographs constitutes a valuable contribution to the theory of ore deposition and to the intricate geology of the best known pre-Cambrian formations. Not only have they an intensive value to local mining men and to pre-Cambrian geologists, but they subserve a broader and scarcely a less important function in the dissemination, through the industrial and scientific world, of information relative to the sources, the extent, and the modes of origin of products which are the dominating factor in the most important metallic industry of America, if not of the world.

T. C. C.

Reviews.

Grundzüge der Geologie des unteren Amazonasgebietes (des Staates Pará in Brasilien). Von Dr. Friedrich Katzer. Leipzig, 1903. Pp. 302, royal 8vo; illustrations and one geologic map of the state of Pará.

The author of this work has brought together and published in a volume of convenient size the chief matters of interest in regard to the geology and geography of the lower Amazonas, and especially of the state of Pará.

The volume opens with a geographic sketch of the region. This is followed by a brief history of the work done on the geology, and biographic notices of the men by whom the work has been done. It is an interesting fact that the bulk of our knowledge of the geology of Brazil dates from a visit made to that county in 1864 by Louis Agassiz. The work of Agassiz himself upon the geology was of no great importance, but his inspiration was far-reaching. C. F. Hartt, one of his assistants, returned to Brazil several times to continue work on the geology, and eventually died in that country. He took with him several assistants—Derby, Rathbun, H. H. Smith, and others—who have continued the work. After Hartt's death, in 1877, Derby remained in Brazil and has devoted his life entirely to the study of Brazilian geology. It was through his influence that descriptions were finally published of the rich Silurian, Devonian, Carboniferous, and Cretaceous faunas of Brazil.

Dr. Katzer himself was formerly geological assistant in the museum of Natural History at Pará, and in that capacity he traveled extensively through the Amazonas country. His interest in the geology of the region has led him to publish this volume even after he has left Brazil.

The biographic part is followed by descriptions of the different groups of rocks, and plates are given of the most important fossils from the fossiliferous horizons.

The volume is one of much value to those who wish to obtain a general knowledge of the geology of the Lower Amazonas region without having to seek it through a large number of papers published at widely different times and places.

J. C. Branner.

The Correlation of Geological Faunas: A Contribution to Devonian Paleontology. By HENRY SHALER WILLIAMS. [Bulletin of the United States Geological Survey, No. 210.] Washington, 1903.

IN the investigation of geologic problems concerned with correlation, two fundamentally different concepts must be kept continually in mind. The first of these has to do with rock strata, the media in which fossil organisms are preserved, and the classification of formations; the second has to do with fossil faunas or assemblages of organisms preserved in the rocks, and the classification of time periods. In the broad correlation of geologic formations the data furnished by the faunas are of prime importance, and too much cannot be said of the value of exhaustive researches upon fossil faunas as faunas.

The paper by Professor Williams on *The Correlation of Geological Faunas* is essentially a treatise upon the methods of investigation of fossil faunas, in which the Middle Devonian fauna of the New York province, characterized by *Tropidoleptus carinatus*, is especially used for illustration.

In the first two chapters of the work, "The Principles of Correlation" and the "Geological Expression of Faunal Migrations" are discussed in a manner applicable to any problem involving the study of fossil faunas. Chapter 3 is devoted to an application of the principles discussed in the preceding chapters, to an investigation of the history of the *Tropidoleptus carinatus* fauna. In treating of the "Shifting of Faunas" in chap. 4, illustrations are again drawn from the Devonian faunas of the New York province. The principles involved, and the effect of the shifting as expressed in the faunas themselves, are fully discussed. In considering the "equivalency" of formations in chap. 5, examples are taken from the correlation of the Devonian formations of New York and Ohio. The sixth and last chapter of the treatise is devoted to the "Bionic Value of Fossils." The application of the data furnished by species, genera, etc., of organisms, for the classification, not of rock formations, but of time periods, is discussed, and the chapter closes with the statement of a proposed "bionic time scale."

In this paper Professor Williams has assembled the more important results, both material and philosophical, which he has secured in the course of his long-continued investigations of the Middle and Upper Devonian faunas of New York. Many of these results have been previously published in various shorter papers, but here they are for the first time brought together in compact form. The paper is full of suggestions and should be studied by every student of fossil faunas.

STUART WELLER.

The Evolution of Earth Structure. New York: Longmans, Green & Co., 1903. By T. MELLARD READE.

THE author concludes that the continents and ocean basins arise from differences in the specific gravities of large sections of the earth. These specific gravities are not stable, but are subject to slow changes consequent upon changes of temperature. A rise of temperature and local increase of volume create protuberances which may be of continental extent. A fall of temperature and decrease of volume lead to depressions, which may culminate in the formation of deeps. "Thus it follows that these departures from the regular spheroidal forms are not original and permanent; nor are they features which have been growing from the dawn of geological history, such as would be likely to occur from a differential radial shrinkage of the earth." Evidence of thermal fluctuations is given by the varying composition, specific gravity, and temperature of lavas from time to time emitted from vents. "The extrusion of lavas is largely due to increase of temperature and consequent increase of volume. Relief by extrusion causes a reduction of temperature, and shrinkage takes place in the supplying reservoir. This results in a subsequent period of quiescence, which lasts until the molten matter of the reservoir again becomes hot enough to compel extrusion."

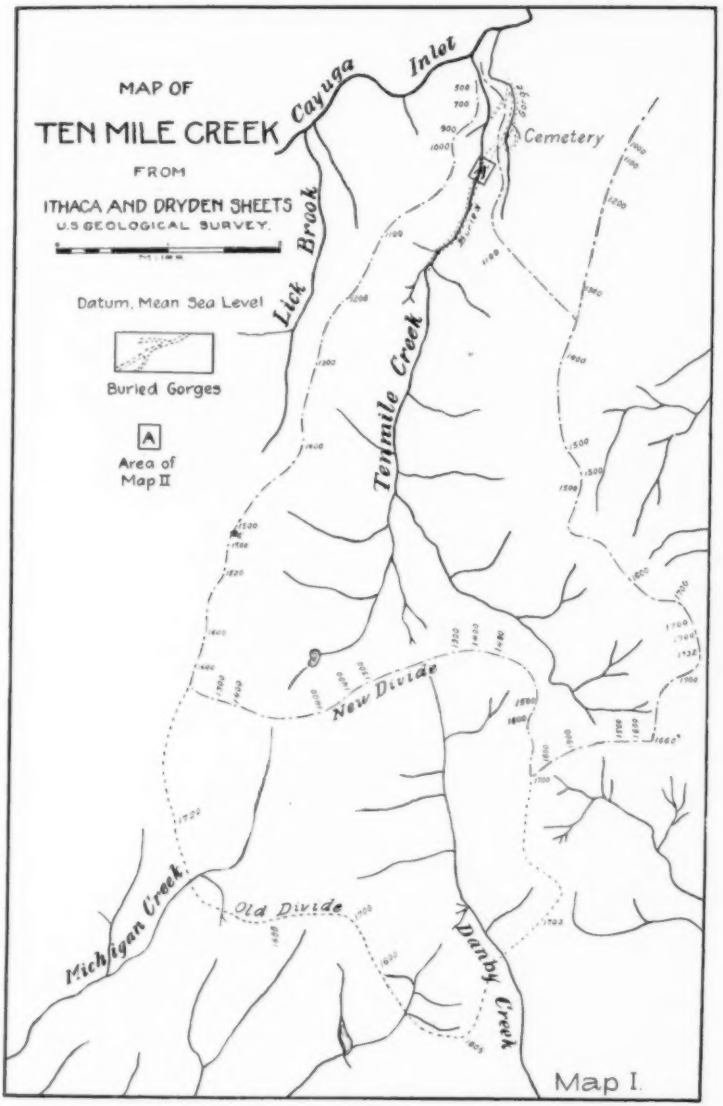
The author holds tenaciously to the theory which he advanced in a former work,[1] that mountain ranges are caused by sedimentation and a subsequent heating of the sediments. Numerous cuts of models illustrating earth movements are introduced, with a full discussion of the experiments.

W. H. E.

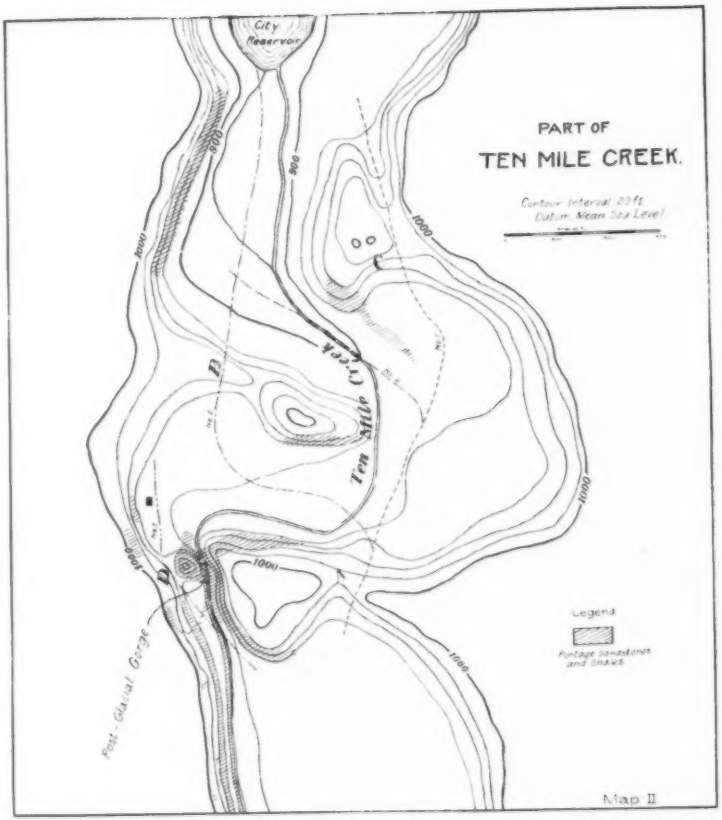
NOTE OF EXPLANATION.

BY an oversight, Maps I and II (Ten Mile Creek) of the paper of Mr. George C. Matson entitled "A Contribution to the Study of the Interglacial Gorge Problem," which appeared in the February-March number of the JOURNAL, were omitted. They are inclosed with this number, and may be inserted between pages 140 and 141 of the February-March number.

[1] *The Origin of Mountain Ranges.*



(This map should be inserted in Vol. XII, No. 2, February-March, 1904, of the JOURNAL OF GEOLOGY, to face page 140.)



(This map should be inserted in Vol. XII, No. 2, February-March, 1904, of the JOURNAL OF GEOLOGY, to face page 142.)